HEWLETT PACKARD

Measurements Reference Guide

HP 5529A
Dynamic Calibrator

Measurements Reference Guide

HP 5529A Dynamic Calibrator

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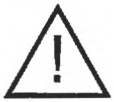
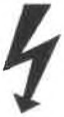
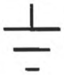


Instruction manual symbol; the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual.



Indicates hazardous voltages.



Indicates ground terminal.

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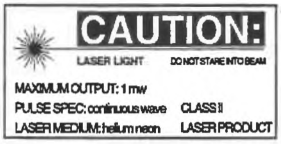
BODILY INJURY OR DEATH MAY RESULT FROM FAILURE TO HEED A WARNING. DO NOT PROCEED BEYOND A WARNING SIGN UNTIL THE INDICATED CONDITIONS ARE FULLY UNDERSTOOD AND MET.

CAUTION

Damage to equipment, or incorrect measurement data, may result from failure to heed a caution. Do not proceed beyond a *CAUTION* sign until the indicated conditions are fully understood and met.

These CAUTION labels are required by the United States Center for Devices and Radiological Health. Failure to follow their instructions may result in personal injury.

This symbol indicates laser radiation.



CAUTION:
LASER LIGHT DO NOT STARE INTO BEAM
MAXIMUM OUTPUT: 1 mw
PULSE SPEC: continuous wave CLASS II
LASER MEDIUM: helium neon LASER PRODUCT

CAUTION: Laser radiation when open.
DO NOT STARE INTO THE BEAM

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About this guide

The *HP 5529A Dynamic Calibrator Measurement Reference Guide* explains how to use the HP 5529A to make machine calibrations.

For complete installation instructions, refer to the *HP 5529A Dynamic Calibrator Installation Guide*. For an overview of the HP 5529A and basic software instructions, refer to the *HP 5529A Dynamic Calibrator Getting Started Guide*. For screen-by-screen help when using the HP 10747A metrology software, use the online help feature.

This guide includes the following sections:

- Chapter 1, "Planning your measurement," provides guidelines to help you plan your measurement correctly.
- Chapter 2, "Linear measurements," explains how to measure distances along a machine's travel path.
- Chapter 3, "Timebase measurements," explains how to make timebase-triggered linear, angular, and straightness measurements.
- Chapter 4, "Angular measurements," explains how to make pitch and yaw measurements.
- Chapter 5, "Straightness measurements," explains how to make straightness measurements. These measurements allow you to determine if a machine part is moving along a straight path.
- Chapter 6, "Squareness measurements in a horizontal plane," explains how to determine if two machine parts in a horizontal plane move perpendicular to each other.
- Chapter 7, "Squareness measurements in a vertical plane," explains how to determine if two machine parts in a vertical plane move perpendicular to each other.

- Chapter 8, “Parallelism measurements,” explains how to determine if two machine parts move parallel to each other. The chapter includes both spindle and coplanar parallelism measurements.
- Chapter 9, "Flatness measurements," explains how to determine if a surface plate is flat.
- Chapter 10, "Way straightness measurements," explains how to determine if a machine part, such as a milling machine way, is straight.
- Appendix A, “Operating specifications,” lists operating specifications for the HP 5529A hardware. It also lists environmental compensation specifications.

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1. Planning your measurements

1. Planning your measurements

1

Planning your measurements

Planning your measurements

This guide provides detailed instructions on making measurements with the HP 5529A dynamic calibrator. However, before you take a machine out of production and begin making measurements, it is important that you plan your measurement carefully. Planning is also an important factor in increasing efficiency.

This chapter provides guidelines to help you plan your measurement correctly. Refer to the *HP 5529A Getting Started Guide* for additional overview information.

Measurement planning guidelines

To minimize machine downtime, before making a new measurement follow these guidelines:

- Determine the travel limits for each axis you will make measurements on.
- Determine the start position for each axis. Also, determine which direction is positive and which is negative.
- Make sure the machine's limit switches are set at the correct positions.
- Determine what type of position feedback system the machine uses. Also, determine its thermal coefficient of expansion. To do this, refer to the machine's maintenance or operations manual or call the manufacturer.
- Determine if the machine's controller is designed to accept an error correction scheme. If it is, determine the type (for example, incremental errors or absolute errors).

Before you change the parameters or the error correction look-up table, refer to the machine tool manual.

- Determine the machine's least programmable resolution unit.

  Note that the detection unit for the error correction table may be different than the least programmable unit. If it is, you must enter a correction factor in the Machine Units box on the Compensation Table screen. Refer to the *HP 5529A Getting Started Guide* and the software's online help system for more information on using this screen. Also, be aware that you may get round-off errors if you try to check a diagonal and disregard the resolution of the X-axis, Y-axis, or Z-axis.

- Determine which format the HP 5529A software should use for its output. Examples are ISO, NMTBA, VDI, and BSI.

  Note that the HP 5529A software can easily switch between formats; however, it is easier to compare calibrations if you choose one format for all calibrations.

- Plan for as many data points as time allows; the more data points you collect the better.

  The data points create a statistical and graphic illustration of machine tool performance. More data points provide a more detailed report of the machine tool's movement (including, for example, its sweet spot and problem areas). Also, the accuracy of the statistical data increases as you include more points.

  However, there is a level at which the data can appear overwhelming on the graph. Use the data analysis features of the HP 5529A and your experience to determine how many points and runs to include in your measurement. The industrial standard or compensation scheme you use may provide additional requirements.

- In determining the measurement interval, choose an interval that is not a multiple of the pitch of the lead screw.

Planning and storing a calibration program

If you are having a program written that will use an auxiliary relay on the machine to trigger the laser reading, do the following:

- Determine the dwell time.
- Map out the connections to the laser remote control switch before starting to test the program.
- Before having the programmer write the program to increment the machine, determine the number of measurements you want to make. Keep in mind that the interval between measurement points must not be an integer multiple of the pitch of the position feedback device. If it is, you might miss some cyclic errors. However, note that some older correction schemes require a fixed interval in order for correct error interpolation.

After the calibration program is written and debugged, you can store it in your CAM system so you can later recall it. It is important that you use the same machine program for each calibration so you can track accuracy and repeatability over time.

Coordinating multiple types of measurements

If you plan to make more than one type of measurement on a machine, follow these guidelines:

- Make all measurements that require the same optics at the same time (one after the other). Then, change the optics to make other types of measurements.

There are three basic types of optics: linear, angular, and straightness. Linear measurements use the linear optics. Angular measurements use the angular optics. Straightness, squareness, and parallelism measurements use the straightness optics.

- If you plan to adjust the machine for angular errors, make the angular measurement first.
- Make linear measurements before making measurements requiring straightness optics.

Triggering options

The HP 5529A offers three types of triggering options. You can select one of these options on the Set Up Measurement screen:

- record button
- auto
- encoder

The rest of this section summarizes each triggering option.

Record button

The record button triggering option allows you to record a measurement manually. With this option, you either press the record button on the remote control unit or select Record on the Collect Data screen to record the measurement. You can also use any switch closure or TTL equivalent with this option.

This is the only triggering option available for arbitrary travel. If the machine encoder is not enabled, you must use this triggering option for angular, straightness, squareness, and parallelism measurements.

The record button triggering option does not use the Trigger Window or Trigger Dwell field on the Set Up Measurement screen. It does use the Target Window field.

Auto

When you use the auto or "soft" trigger option, the system automatically makes a measurement when the machine tool is within range of the target and has stopped or slowed down sufficiently to take a stable reading.

You can use the auto triggering option for timebase measurements. If you do, you must enable the machine encoder for any measurement other than linear.

For linear measurements, the system uses the encoder position if you enable the encoder. Otherwise, the system uses the laser position.

The auto triggering option uses the Target Window, Trigger Window, and Trigger Dwell fields on the Set Up Measurement screen.

If repeatability is a problem, increase your dwell time (on the Set Up Measurement screen). You might have to do this several times to obtain good results.

Encoder

When you use the encoder option, the machine tool's encoder pulses serve as the position reference enabling you to make measurements "on-the-fly." The machine does not stop and make a measurement; it automatically makes the measurement when the encoder reaches the target position.

Two types of encoders are supported: A quad B and Up/Down.

If you are using the encoder triggering option, be sure the encoder resolution on the Set Up Laser screen matches the position distance of one encoder count.

The target list must be evenly spaced since a measurement is taken every *n*th encoder pulse.

Extended resolution cannot be used with the encoder triggering option since extended resolution requires the machine tool to be stopped at each measurement point.

The encoder triggering option does not use the Target Window, Trigger Window, or Trigger Dwell field on the Set Up Measurement screen.

Using online help

This guide shows the software screens you will use in making measurements, but it does not provide field-by-field descriptions. For information on completing or using a specific field, use the online help.

To access online help for an entire screen, select the information (i) button.

To access online help for a specific field or button, follow these steps:

1. **Select the field or button you want help with. There are two ways of doing this:**
    - Tab to the field or button (but do not press Enter).
    - Use the mouse to move the cursor to the field or button, then press and hold the left mouse button. Next, "drag" the mouse cursor off of the field or button and release the mouse button.
2. **Press F1.**

    The help text for the field or button that is selected is displayed in a new window.
3. **Close the help window by pressing Alt-F4. Or, use the mouse to select Exit on the File menu.**

2. Linear measurements

2. Linear measurements

2

Linear measurements

Linear measurements

This chapter explains how to make linear measurements at multiple points along a machine's travel path. Before performing the procedures described in this chapter, you must understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide.* For operating specifications, see Appendix A.

1 Two posts and height adjusters, p/n 10785A

2 Linear interferometer, p/n 10766A

3 Knurled attachment screws

4 Two linear retroreflectors, p/n 10767A

5 Base, p/n 10784A

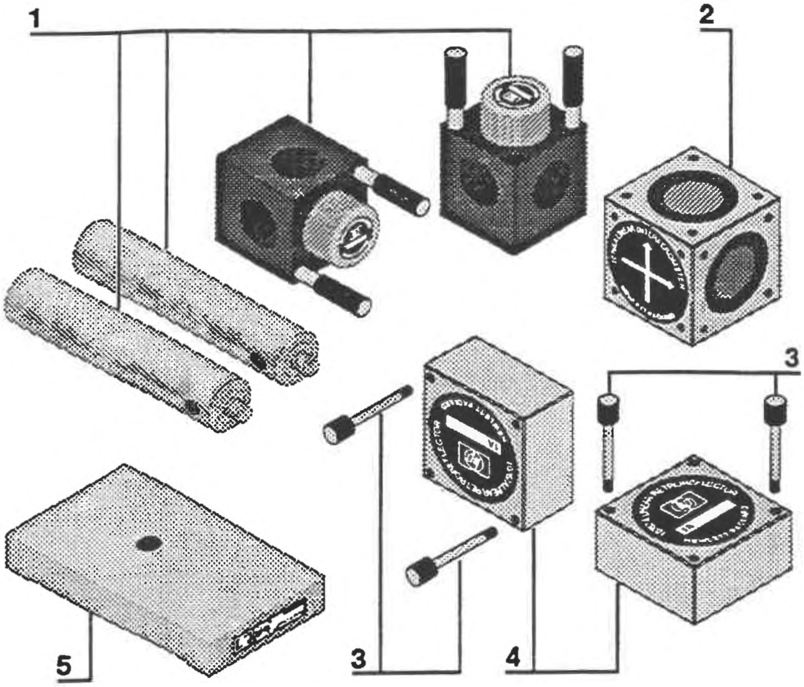


Figure 2–1. Required hardware for linear measurements

Setting up for the measurement

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter to make a linear measurement. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head, remote control unit, and sensors (if used) to the connectors on the 10886A and 10887A boards installed in the computer.**

The connectors are either on the rear or the side of the computer.

3 **Plug in and turn on all equipment.**

4 **Start the metrology software.**

The Metrology Main Menu is displayed.

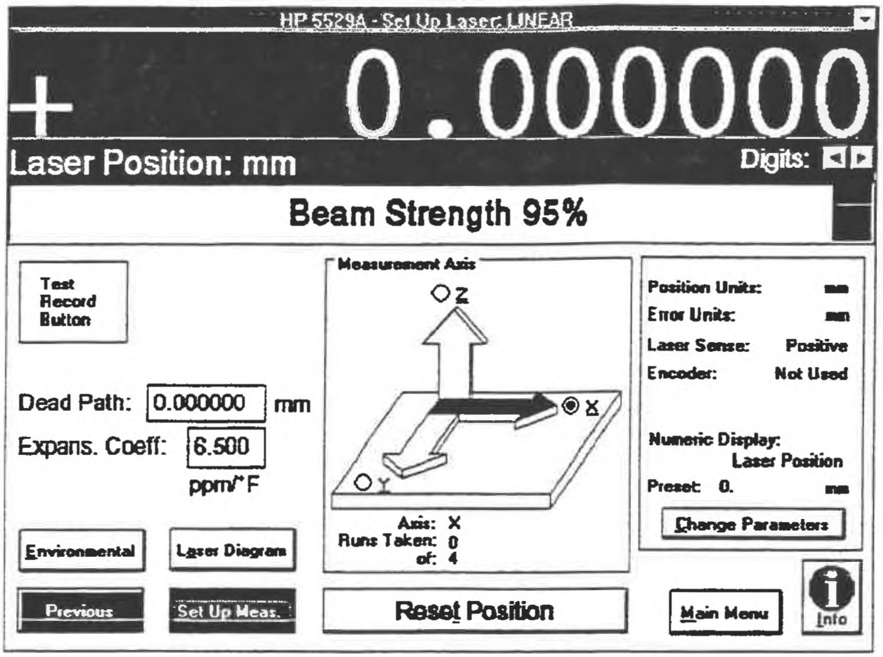
5 **On the Metrology Main Menu, select Linear.**

The Set Up Laser: Linear screen (Figure 2–2) is displayed.

Alternately, you can open an existing linear measurement setup file from your database by selecting Recall Data on the Main Menu.

6 **Complete the fields on the Set Up Laser: Linear screen.**

If necessary, use the online help.


HP 5529A - Set Up Laser: LINEAR
Digits:
Test Record Button
Measurement Axis
Z
X
Y
Environmental
Laser Diagram
Previous
Set Up Meas.
Reset Position
Change Parameters
Main Menu
Info

+ 0.000000

Laser Position: mm

Beam Strength 95%

Dead Path: 0.000000 mm

Expans. Coeff: 6.500 ppm/°F

Axis: X
Runs Taken: 0
of: 4

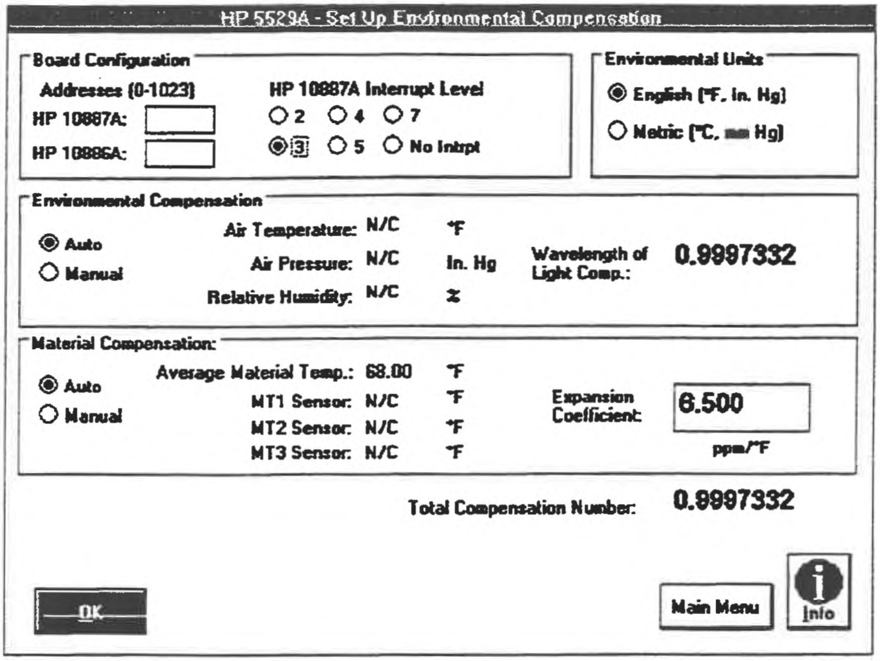
Position Units: mm
Error Units: mm
Laser Sense: Positive
Encoder: Not Used

Numeric Display: Laser Position
Preset: 0. mm

Figure 2–2. Set Up Laser: Linear screen

7 **Select Environmental.**

The Set Up Environmental Compensation screen is displayed (Figure 2–3).



HP 5529A - Set Up Environmental Compensation

Board Configuration

Addresses (0-1023)

HP 10887A:

HP 10886A:

HP 10887A Interrupt Level

○ 2 ○ 4 ○ 7

● 3 ○ 5 ○ No Intrpt

Environmental Units

● English (°F, In. Hg)

○ Metric (°C, mm Hg)

Environmental Compensation

● Auto

○ Manual

Air Temperature: N/C °F

Air Pressure: N/C In. Hg

Relative Humidity: N/C %

Wavelength of Light Comp.: 0.9997332

Material Compensation:

● Auto

○ Manual

Average Material Temp.: 68.00 °F

MT1 Sensor: N/C °F

MT2 Sensor: N/C °F

MT3 Sensor: N/C °F

Expansion Coefficient: 6.500 ppm/°F

Total Compensation Number: 0.9997332

Figure 2–3. Set Up Environmental Compensation screen

The system uses information entered on this screen to compensate for measurement inaccuracies caused by environmental factors such as air temperature.

If you are using sensors, the system automatically compensates for measurement inaccuracies caused by environmental conditions. Go directly to "Placing and using the sensors."

If you are not using sensors, you must manually enter values on this screen that will compensate for measurement inaccuracies. Continue with step 8.

8 **On the Set Up Environmental Compensation screen, do the following:**

a In the Environmental Compensation box, select Manual.

b Use the default values or enter new values in the following fields:

- Air Temperature
- Air Pressure
- Relative Humidity

c In the Material Compensation box, select Manual.

d Use the default values or enter new values in the following fields:

- Avg. Material Temp
- Expansion Coefficient

The system saves the values last entered on this screen. It uses them in all linear measurement calculations unless you enter new values or select Auto.

For instructions on completing the other fields on the screen, use the online help.

9 **When you have completed the screen, select OK.**

You are returned to the Set Up Laser: Linear screen.

You are now ready to mount and align the optics on the target machine. Go directly to "Mounting and aligning the optics on the target machine."

Placing and using the sensors

Environmental conditions in your work environment affect the accuracy of your linear measurement. These conditions include air temperature, air pressure, relative humidity, and material temperature. The HP 5529A uses optional air and material sensors to measure these conditions and adjust the measurements accordingly.

- **1** Laser head
- **2** Air sensor
- **3** Material temperature sensor
- ***** Sensor cables connected to a PC

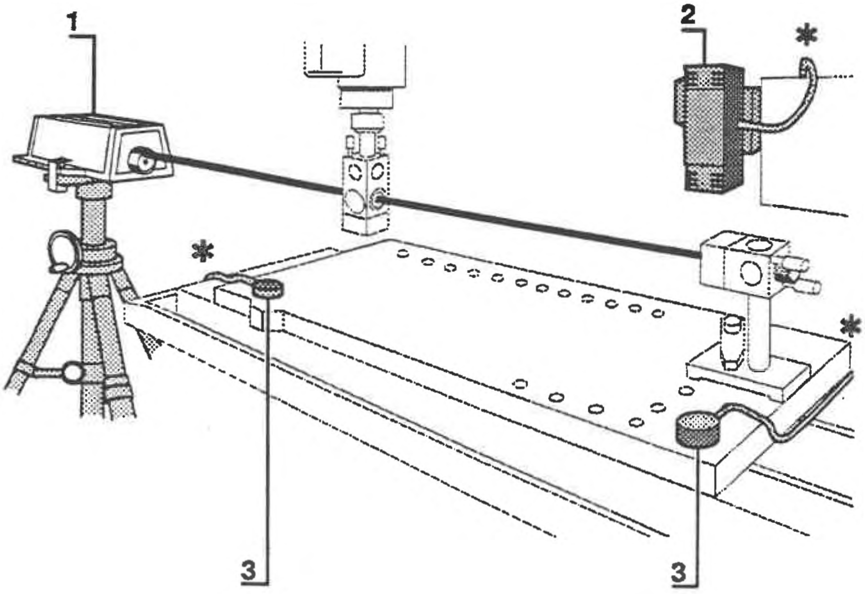


Figure 2–4. Air and material temperature sensors

Before using the following procedure, be sure the air and material sensors are connected to your computer. If they are not connected, refer to the *HP 5529A Getting Started Guide* for instructions.

To automatically adjust for the effects of environmental conditions on the laser reading, follow these steps:

CAUTION In placing the sensors on the machine, be sure the sensors and their cables will not be a hazard to people, will not interfere with your measurement, and will not be damaged by machine movement.

1. **Place the air sensor as close as possible to the actual measurement path.**

   Never place the air sensor directly below the laser beam. The sensor is a source of heat and can cause inaccuracies in your measurements. For more information on placing the sensors, refer to the *HP 5529A Getting Started Guide*.

2 **Set the humidity switch on the side of the air sensor to the setting closest to the relative humidity in your area.**

For more information on setting the humidity switch, refer to the *HP 5529A Getting Started Guide*.

3 **Place the material temperature sensors where recommended by calibration standards such as ANSI B-5.**

For a machine with a table, it is usually sufficient to place the sensors on the table.

4 **On the Set Up Environmental Compensation screen, select Auto in the Environmental Compensation and Material Compensation boxes.**

The sensors now provide the current environmental values to the metrology software.

For instructions on completing the other fields on the screen, use the online help.

5 **When you have completed the screen, select OK.**

You are returned to the Set Up Laser: Linear screen.

You are now ready to mount and align the optics on the target machine.

Mounting and aligning the optics on the target machine

This section explains how to correctly mount and align the interferometer assembly and the separate retroreflector on the target machine before making a measurement.

Notes

- The figures in this chapter use a machine with a spindle as an example. Although your machine may be different, the general procedures described here still apply.
- If angular optics are already mounted on the target machine, you can install the linear optics by simply changing the optics without changing the mounting hardware.

Mounting the optics

To mount the optics on the target machine, follow these steps:

CAUTION If you are not using the HP 5529A to test for machine vibration, then before mounting the optics or making a linear measurement be sure the laser head and the target machine are as stable and free of vibration as possible. Movement of the optics, even from slight vibration, reduces the accuracy of your measurement and may cause the receiver on the laser head to lose beam strength during the measurement.

1 **Position the laser head along the axis most suitable for the measurement you want to make (Figure 2–5).**

2 **Adjust the laser head to the approximate height at which you will mount the optics.**

3 **Move the moveable part of the target machine as close as possible to the laser head.**

This helps prevent the moveable part from hitting the laser head during alignment and measurement procedures.

4 **Determine how to position the optics. See Figure 2–5 for sample setups, and use the following guidelines:**

- Mount one optic where the tool mounts. Mount the other optic where the workpiece mounts. Make sure the interferometer assembly is between the retroreflector and the laser head.
- If you want to measure along an axis perpendicular to the laser beam as it leaves the laser head, mount the interferometer assembly on a part of the machine that does not move.

A Measurement along the X-axis

B Measurement along the Y-axis with the laser beam bent horizontally 90° to the retroreflector

C Measurement along the Z-axis with the laser beam bent vertically 90° to the optics

****

1	Retroreflector mounted on a height adjuster with a base and post
2	Interferometer assembly mounted in a spindle
3	Laser beam
4	Laser head
5	Retroreflector mounted in a spindle
6	Interferometer assembly mounted on a height adjuster with a base and post

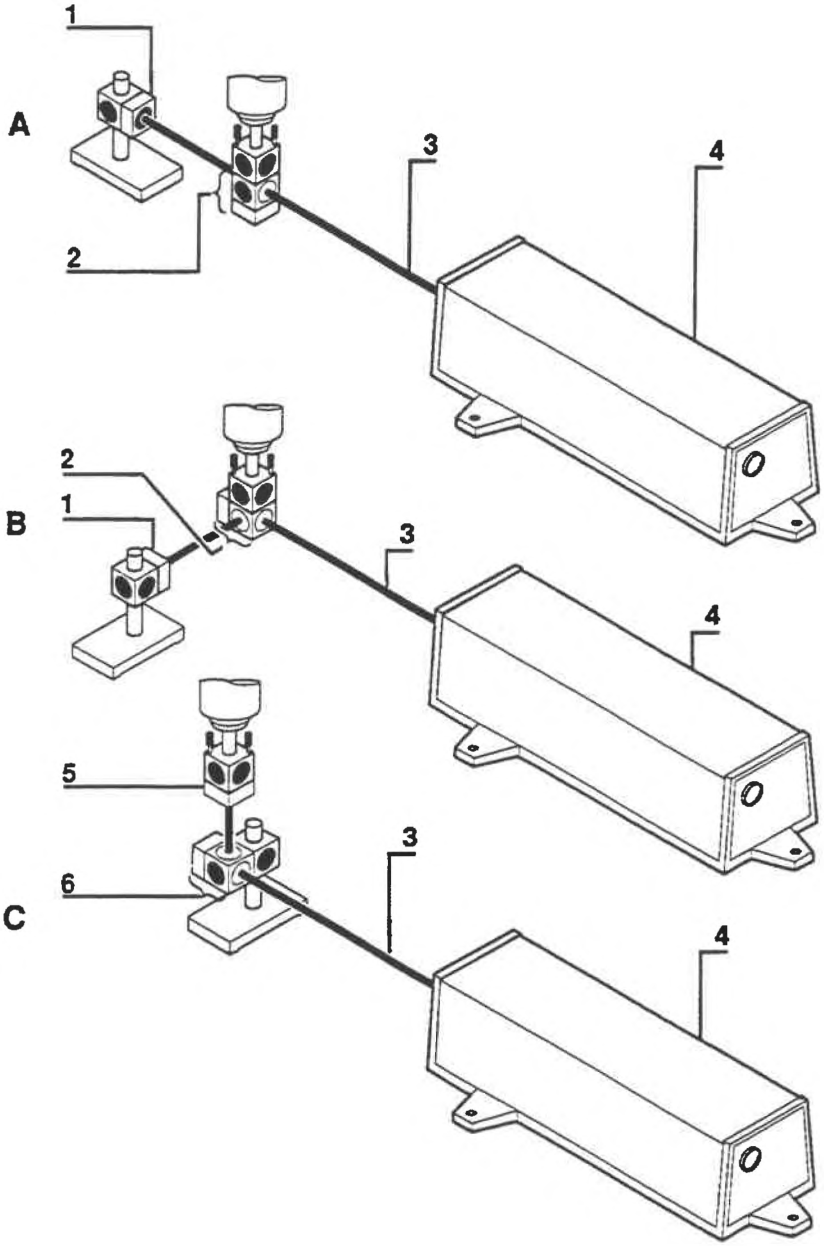


Figure 2–5. Positioning of linear optics

5 **Attach the interferometer to a retroreflector by following these steps:**

a Place one retroreflector on the interferometer so one of the arrows on the interferometer's label points toward the retroreflector (Figure 2-6).

b Attach the two optics using the knurled screws included with the retroreflector.

In the rest of this chapter, this assembly made up of the interferometer and the retroreflector is referred to as the "interferometer assembly."

1 Knurled screws
2 Retroreflector
3 Interferometer

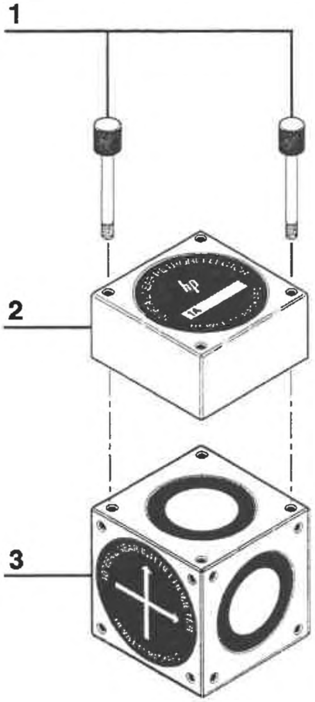


Figure 2–6. Assembling the interferometer assembly

6 **Depending on the axis along which you are measuring, do one of the following:**

- Mount the interferometer assembly on the machine table as shown in Figure 2–7. The arrow on the interferometer's label that does not point to the retroreflector must point to the external reflector; that is, away from the laser head.

- Or, assemble and mount the retroreflector on the machine table as shown in Figure 2–8.

Note If you plan on making a straightness or squareness measurement later, position the top of the height adjuster even with the top of the post so you can easily change optics. Then, use the adjustment knobs on the laser head so the return beam enters the laser head's lower port.

1 Interferometer assembly

2 Height adjuster and post

3 Base

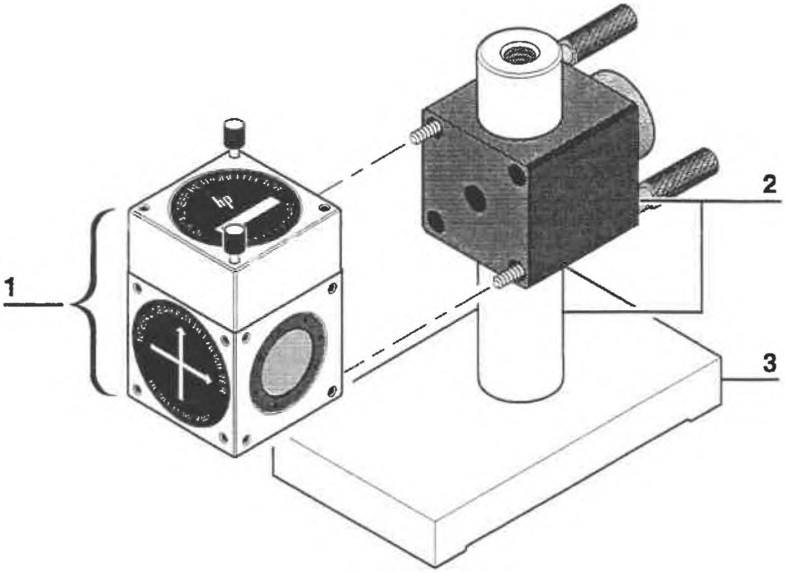


Figure 2–7. Interferometer assembly table mounting

1 Retroreflector

2 Post and height adjuster

3 Base

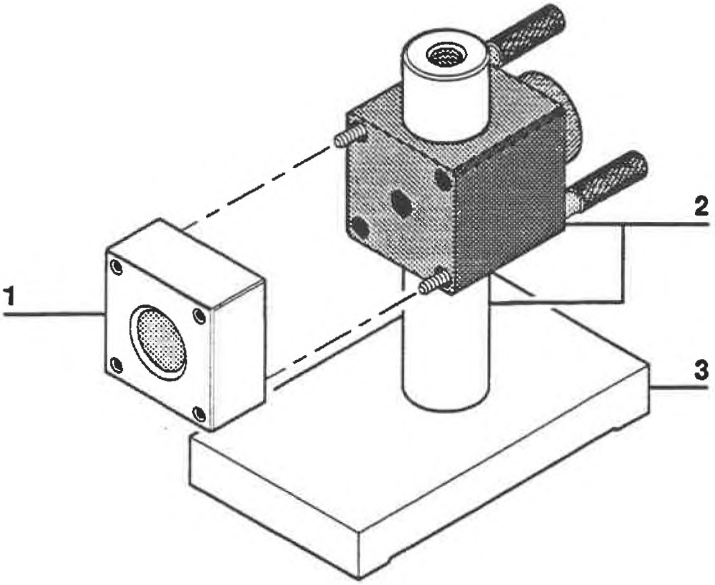


Figure 2–8. Retroreflector table mounting

In the following steps, you will fasten a post to the height adjuster on the optic you are mounting in the machine's spindle. (You will then insert the post into the spindle and secure it.) You can connect the post to the height adjuster in one of two ways as explained in the next step.

7 **For the optic you plan to mount on the spindle, do one of the following:**

- Insert the post into the optic's height adjuster and tighten the knurled knob.
- Or, remove the large knurled knob from the height adjuster and screw in the post as shown in Figure 2–9.

The method you choose to mount the optic is up to you.

A Removing the large knurled knob

B Screwing in the post

****

1 Spindle

2 Post

3 Height adjuster

4 Large knurled knob

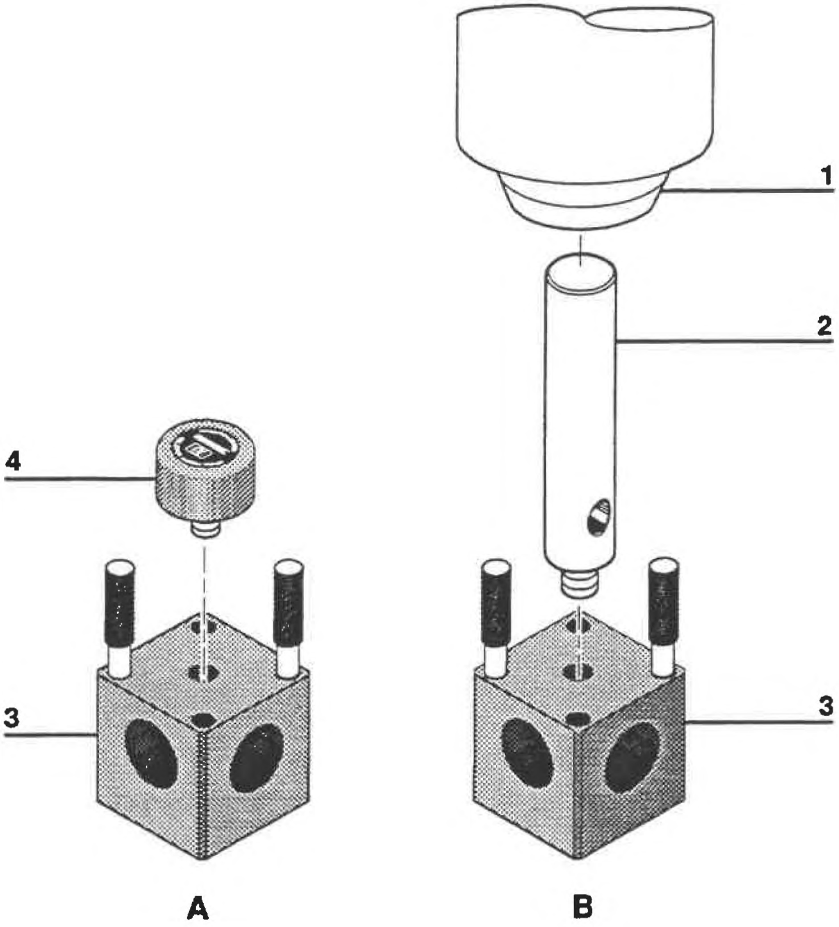


Figure 2–9. Alternate height adjuster mounting

8 Mount the interferometer assembly on the spindle as shown in Figure 2–10. Or, mount the retroreflector on the spindle as shown in Figure 2–11.

1 Post and height adjuster

2 Interferometer assembly

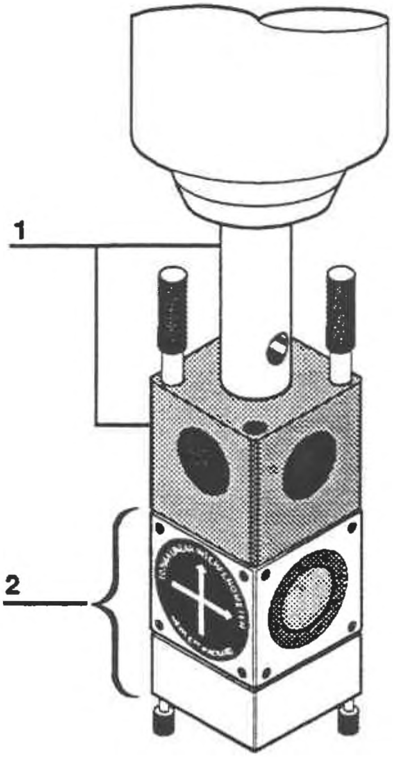


Figure 2–10. Interferometer assembly spindle mounting

1 Post and height adjuster

2 Retroreflector

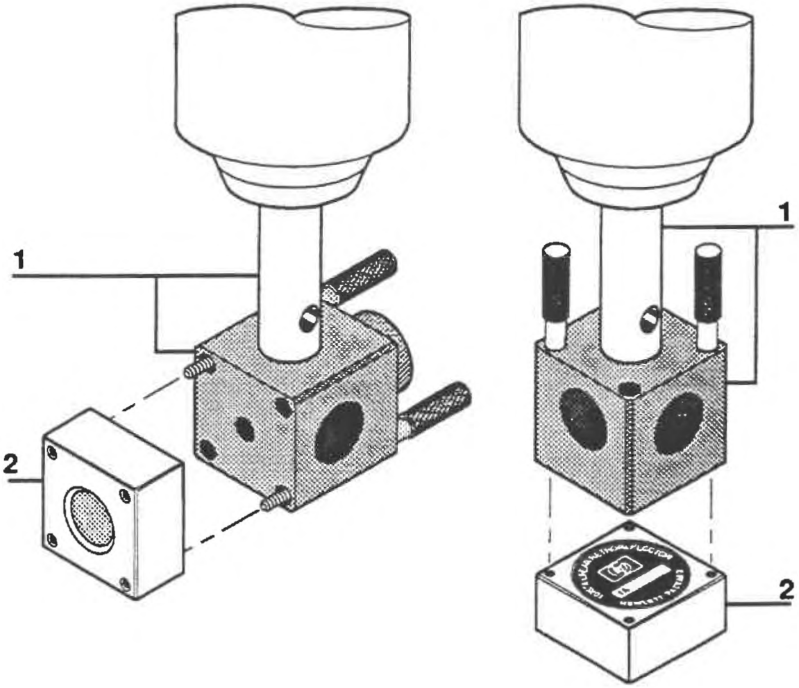


Figure 2–11. Retroreflector spindle mounting

Although posts, bases, and height adjusters provide considerable adaptability for mounting optics, there may be some situations when you need added flexibility. Figure 2-12 shows how you can increase adaptability by using additional hardware.

1 C-clamp
2 Base
3 Post and height adjuster
4 Interferometer or retroreflector

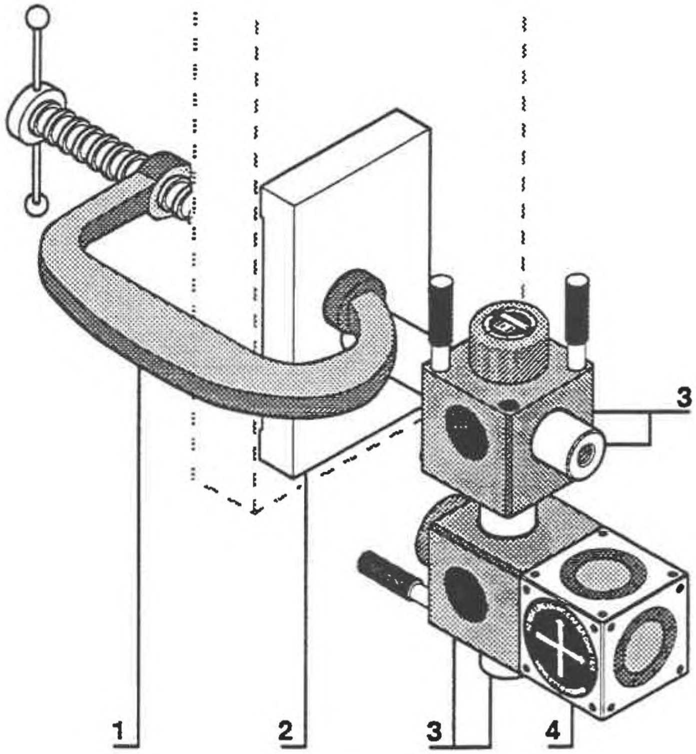


Figure 2–12. Increased mounting adaptability

9 **Gently tap each optic with your finger to ensure its mounting is rigid and free of vibration.**

If you feel any vibration, tighten all connections in the mounting.

You are now ready to align the optics.

Aligning the optics

To align the optics on the target machine, follow these steps:

1 **Set the laser head's upper port to the small aperture by turning the upper aperture control (Figure 2–13).**

2 **Rotate the target into position on the laser head's lower port by turning the lower aperture control.**

3 **Set the laser head's turret ring to OTHER.**

4 **Adjust the laser head so the beam enters the lens on the interferometer and the return beam is on or near the target on the laser head's lower port.**

1 Turret ring set to OTHER
2 Upper aperture control
3 Upper port
4 Lower port with target showing
5 Lower aperture control

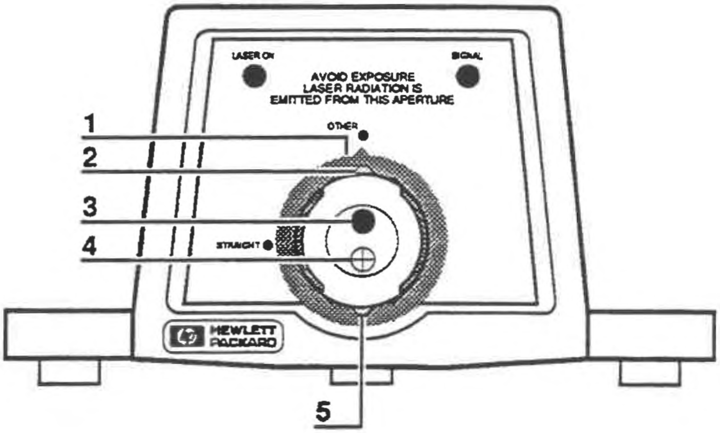

LASER ON
SIGNAL
AVOID EXPOSURE
LASER RADIATION IS
EMITTED FROM THIS APERTURE
OTHER
STRAIGHT
HEWLETT PACKARD
1
2
3
4
5

Figure 2–13. Front panel of the laser head

5 **Adjust the interferometer assembly or the laser head so the return beam (seen as a dot on the laser head) is centered on the laser head's target.**

To adjust the interferometer up or down, loosen the large knob on the height adjuster, move the interferometer up or down, then tighten the knob. You can also move the interferometer left or right or rotate it left or right.

You can adjust the laser head by rotating it, translating it, or both.

6 **Secure the interferometer assembly to the target machine, maintaining the laser beam's position in the center of the laser head's target.**

To secure the interferometer assembly, use a clamp or similar device. Observe the following guidelines when securing the interferometer assembly:

- If you are securing the optic to the spindle, lock the spindle in place.
- If you are securing the optic to a surface such as a machine table, make sure the surface is flat so the optic will not rock.
- When using a clamp to secure the optic, try to cover as much of the optic's base as possible with the clamp so the attachment is secure.

Note It is helpful to orient the lines visible in the window of the retroreflector as shown in Figure 2–14. If they are not, the retroreflector will absorb light from the laser rather than reflect the light. This renders the return dots fuzzy and makes alignment more difficult. If you need to reorient the retroreflector, follow these steps:

1. Remove the retroreflector from the height adjuster.
2. Rotate the retroreflector 90 degrees in either direction.
3. Reattach the retroreflector to the height adjuster.

1 Correct orientation of internal lines

2 Retroreflector

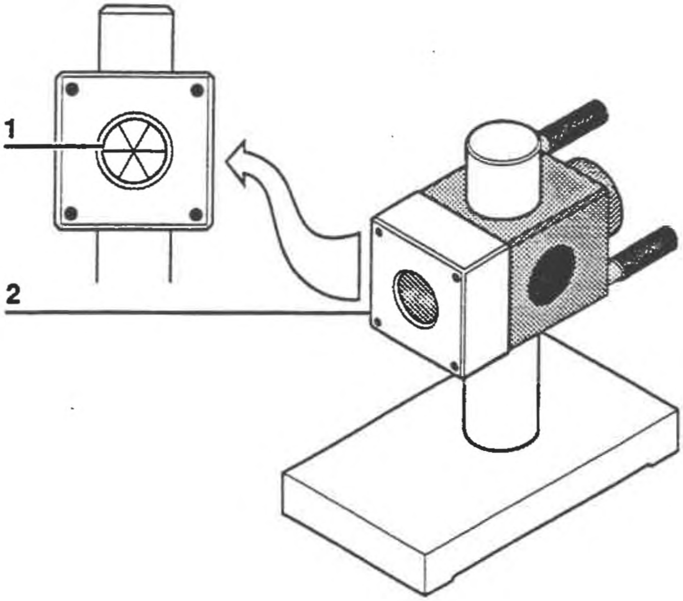


Figure 2–14. Correct retroreflector orientation

7 **Move the retroreflector as close as possible to the interferometer assembly without allowing the two to touch. Less than 25 mm (1 inch) is preferred. Then, adjust the retroreflector so its return beam is centered on the target covering the laser head's return port and overlays the interferometer return beam.**

In the rest of this chapter, the position of the retroreflector near the interferometer assembly as described above is referred to as the "start position."

Note To perform an alignment when the two optics are close together like this, adjust the optics only, not the laser head. Adjust the laser head only when the optics have been moved apart.

8 **Secure the retroreflector to the target machine, maintaining its return beam's position in the center of the laser head's target.**

See the guidelines for securing an optic listed in step 6.

You are now ready to align the laser beam to the machine's travel path.

If your measurement distance is less than 350 mm (14 inches), go directly to "Aligning the laser beam to the machine's travel path for short-range measurements."

If your measurement distance is greater than 350 mm (14 inches), continue with the next section, "Aligning the laser beam to the machine's travel path for long-range measurements."

Aligning the laser beam to the machine's travel path for long-range measurements

Use this procedure if your measurement distance is greater than 350 mm (14 inches). Before proceeding, make sure the machine is at the start position. To align the laser beam to the machine's travel path, follow these steps:

1 **While watching the return beam on the laser head, move the machine's moveable part away from the laser head.**

If the retroreflector's dot moves away from the target cross hairs on the laser head, the laser beam is not aligned with the travel path. Continue with step 2.

If the dot does not move by the time the moveable part reaches the last measurement point, the laser beam is already aligned with the travel path. Skip the rest of these steps and go directly to "Making the measurement."

2 **Make the following adjustments:**

a Carefully tilt the laser head up or down until the dot moves vertically twice the distance in the opposite direction it moved when you performed step 1.

For example, if the dot moved 25 mm (1 inch) below the target when you moved the machine's moveable part, adjust the laser head until the dot is 25 mm (1 inch) *above* the target.

b Carefully rotate the laser head left or right until the dot moves horizontally twice the distance in the opposite direction it moved when you performed step 1.

3 **Move the machine's moveable part back to its start position.**

Usually, the dot will now be partially or completely off the target crosshairs.

4 **Translate the laser head up or down and left or right until**

- the beam from the laser head completely enters the interferometer's lens
- both dots overlap the crosshairs on the laser head's target

5 **Repeat steps 1 through 4 until the machine's moveable part reaches the last measurement point or the dots no longer move from their position on the crosshairs.**

You are now ready to make the measurement. Go directly to "Making the measurement."

Aligning the laser beam to the machine's travel path for short-range measurements

Use this procedure if your measurement distance is less than 350 mm (14 inches). Before proceeding, make sure the machine is at the start position and the small aperture is in position over the upper port on the laser head. To align the laser beam to the machine's travel path, follow these steps:

1 **Place a reference mirror or a similar reflecting device between the interferometer and retroreflector.**

2 **Make sure the reflecting device you use**

- is aligned so its reflecting surface is perpendicular to the machine's travel path
- reflects the beam parallel to the machine's travel path back to the upper port on the laser head

If you use a reference mirror and the machine has T slots, you can align the reference mirror so it is parallel to the T slots.

3 **Tilt the laser head up or down and rotate it left or right until the return beam from the reference mirror forms a halo around the aperture in the upper port.**

You are now ready to make the linear measurement.

Making the measurement

In this procedure, you make manual measurements as you move the machine's moveable part. If you are using sensors, make sure they are properly placed and the software is set up correctly. (Refer to the *HP 5529A Getting Started Guide* for complete instructions on using the software and the sensors.)

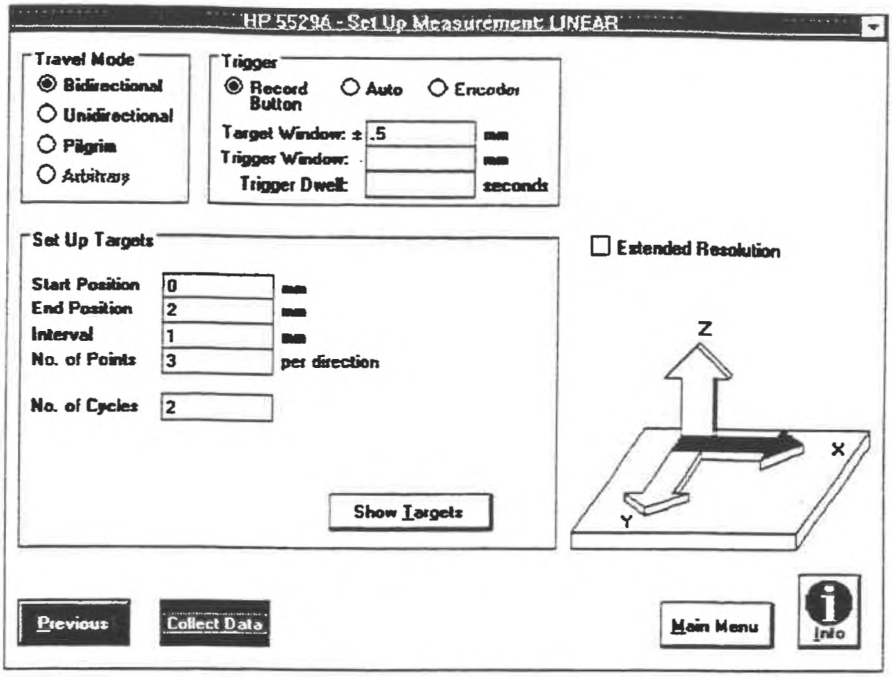
This procedure explains how to make measurements using the Record button in the software and the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

To make the measurement, follow these steps:

1 **Move the moveable optic so it is at its start position.**

2 **On the Set Up Laser: Linear screen, select Set Up Meas.**

The Set Up Measurement: Linear screen is displayed (Figure 2-15).



HP 5529A - Set Up Measurement LINEAR

Travel Mode
● Bidirectional
○ Unidirectional
○ Pilgrim
○ Arbitrary

Trigger
● Record Button
○ Auto
○ Encoder
Target Window: ± .5 mm
Trigger Window: mm
Trigger Dwell seconds

Set Up Targets
Start Position 0 mm
End Position 2 mm
Interval 1 mm
No. of Points 3 per direction
No. of Cycles 2

☐ Extended Resolution

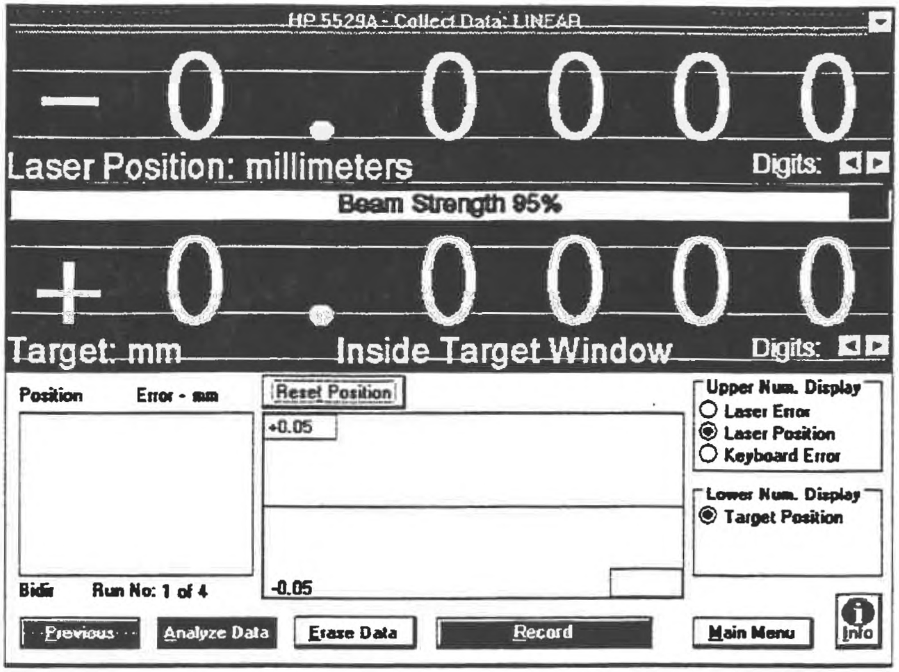
Figure 2–15. Set Up Measurement: Linear screen

3 **Complete the fields on the Set Up Measurement: Linear screen.**

If necessary, use the online help.

4 **Select Collect Data.**

The Collect Data: Linear screen is displayed (Figure 2–16).


HP 5529A - Collect Data: LINEAR
Position
Error - mm
Reset Position
+0.05
-0.05
Bidir
Previous
Analyze Data
Erase Data
Record
Main Menu
Info
Digits:

-0.0000
Laser Position: millimeters
Beam Strength 95%

+0.0000
Target: mm
Inside Target Window

Run No: 1 of 4

Upper Num. Display
○ Laser Error
● Laser Position
○ Keyboard Error

Lower Num. Display
● Target Position

Figure 2–16. Collect Data: Linear screen

5 **On the Collect Data: Linear screen, select Reset Position.**

This tells the system that the current position of the retroreflector is the "zero" point from which all distances will be measured.

If necessary, use the online help to complete the rest of the fields on this screen.

6 **Move the machine's moveable part to the first measurement point.**

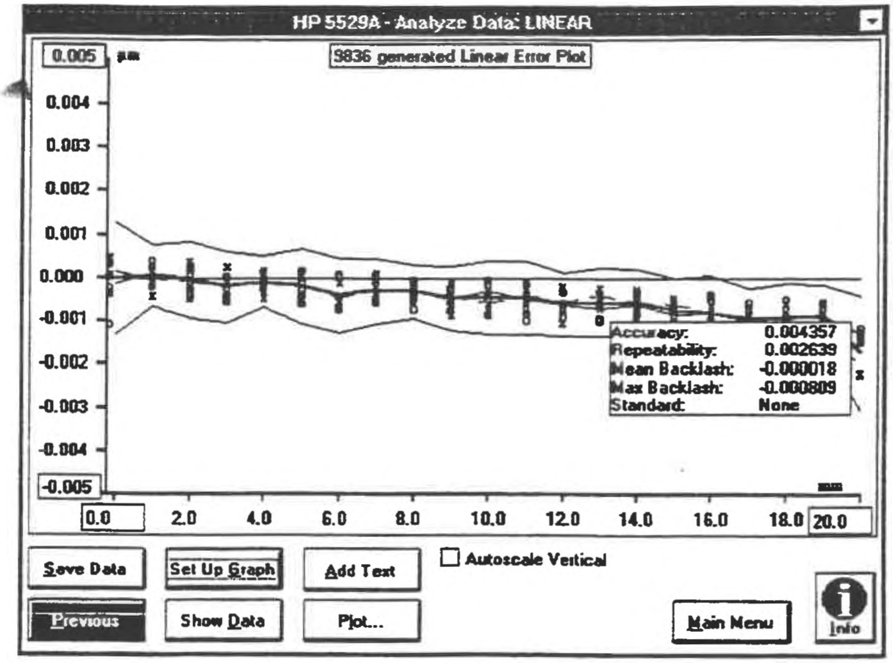
7 **Select Record.**

If you are using the optional remote control unit, press the Record button.

8 **Continue moving the machine's moveable part to each point and recording measurements until the machine has reached the last measurement position.**

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. Move the retroreflector back to the last position measured before the beam was broken, then select Reset Laser to reset the system.

After you record the last measurement, the Analyze Data: Linear screen is displayed (Figure 2–17).


HP 5529A - Analyze Data: LINEAR
5836 generated Linear Error Plot
0.005
µm
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
-0.005
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
mm
Save Data
Set Up Graph
Add Text
☐ Autoscale Vertical
Previous
Show Data
Plot...
Main Menu
Info

Accuracy: 0.004357
Repeatability: 0.002639
Mean Backlash: -0.000018
Max Backlash: -0.000809
Standard: None

Figure 2–17. Analyze Data: Linear screen

9 On the Analyze Data: Linear screen, select Save Data to create or update a data file with the measurement data.

Refer to the *HP 5529A Getting Started Guide* and online help for more information about using this screen. Otherwise, you are finished making the measurement.

3. Timebase measurements

3. Timebase measurements

3

Timebase measurements

Timebase measurements

This chapter explains how to make timebase-triggered linear, angular, and straightness measurements. With timebase measurements, you can determine the position, velocity, and acceleration of these variables as a function of time.

Timebase measurement data can assist you in deciding if your machine tools perform accurately. For example, you can determine how to properly tune servo drives and make necessary mechanical adjustments by analyzing the following elements:

- linear velocity profile and constant-velocity measurements
- feed rate adjustment
- relative vibrations (linear, angular, and straightness)
- “torque profile” (angle of rotation as a stage or gantry starts or stops rapidly)

Timebase measurement data is also helpful in machine drift testing. As you make measurements, you can create your own uses and applications for timebase measurements.

Because setup, optics mounting, and alignment procedures for timebase measurements are the same as those for other linear, angular, and straightness measurements, you are referred to the following chapters for most instructions: Chapter 2, “Linear measurements,” Chapter 4, “Angular measurements,” and Chapter 5, “Straightness measurements.”

Before performing the procedures described in this chapter, you must fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*.

Setting up for the measurement

If you have not done so, perform the following setup procedures before using the rest of the instructions in this chapter to make a timebase measurement. Refer to the *HP 5529A Getting Started Guide* for more detailed instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the sensors (if used), the laser head, and the optional remote control unit to the connectors on the HP 10886A and HP 10887A boards installed in the computer.**

The connectors are either on the rear or on the side of the computer.

3 **Plug in and turn on all equipment.**

4 **Start the metrology software.**

The Metrology Main Menu is displayed.

5 **On the Metrology Main Menu, select Other Meas.**

The Other Measurements screen is displayed (Figure 3-1).

Or, you can open an existing timebase setup file by selecting Recall Data on the Main Menu.

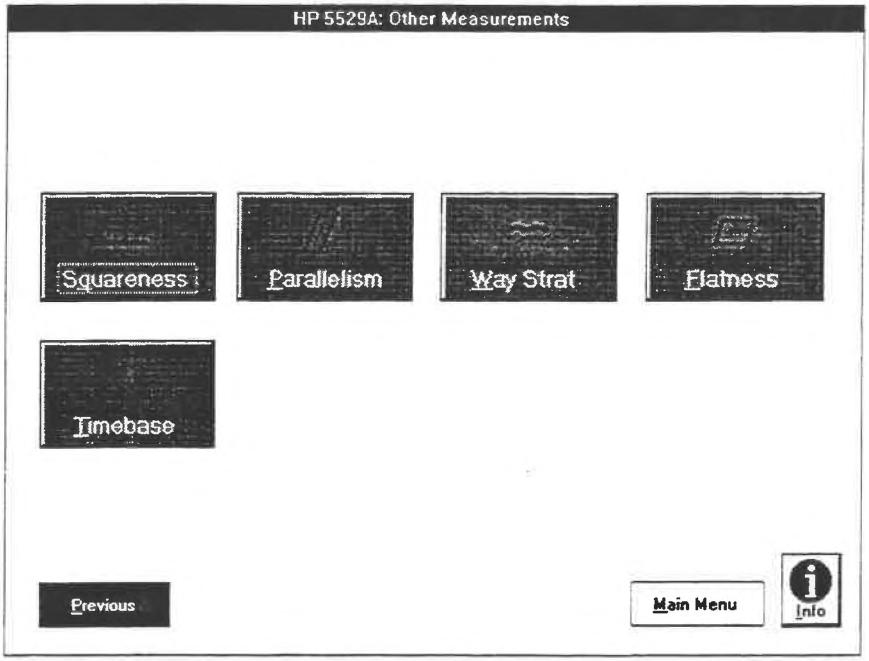
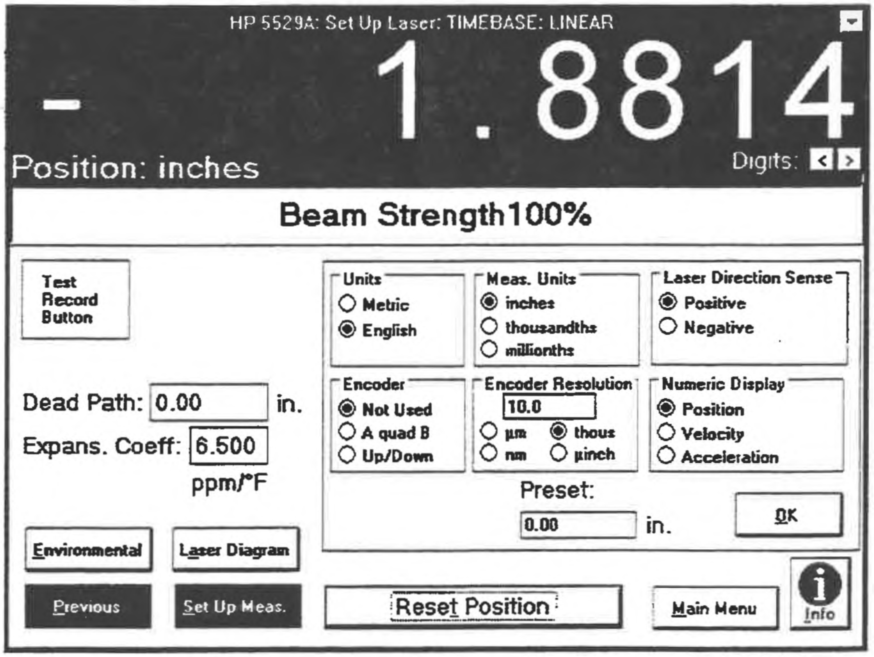

HP 5529A: Other Measurements
Squareness
Parallelism
Way Strat
Flatness
Timebase
Previous
Main Menu
Info

Figure 3-1. Other Measurements screen

6 **On the Other Measurements screen, select Timebase.**

The Set Up Laser: TIMEBASE screen (Figure 3-2) is displayed.



HP 5529A: Set Up Laser: TIMEBASE: LINEAR

- 1.8814

Position: inches

Beam Strength100%

Dead Path: 0.00 in.

Expans. Coeff: 6.500 ppm/°F

Units: ○ Metric ● English

Meas. Units: ● inches ○ thousandths ○ millionths

Laser Direction Sense: ● Positive ○ Negative

Encoder: ● Not Used ○ A quad B ○ Up/Down

Encoder Resolution: 10.0 ○ µm ● thous ○ nm ○ µinch

Numeric Display: ● Position ○ Velocity ○ Acceleration

Preset: 0.00 in.

Figure 3-2. Set Up Laser: TIMEBASE screen

The system automatically sets up to measure linear movement along the X-axis. To choose different settings, follow these steps:

1 **In the Measurement Axis box, select Ang for angular measurement or Str for straightness measurement.**

2 **Select an axis.**

3 **If you are measuring angular, select pitch or yaw. If you are measuring straightness, select vertical or horizontal.**

4 **To redefine the laser setup parameters, select Change Parameters.**

If necessary, use the online help.

Note The following options are not available for timebase measurements: encoder, averaging, and extended resolution.

If you selected linear, complete the Set Up Environmental Compensation screen following steps 7 through 9 in "Setting up for the measurement" in Chapter 2.

If you selected straightness, complete the instructions in "Positioning the laser head and target machine" in Chapter 5.

You are now ready to mount and align the optics on the target machine; continue with the next section.

Mounting and aligning the optics on the target machine

For linear measurements, complete the instructions in "Mounting and aligning the optics on the target machine" in Chapter 2.

For angular measurements, complete the instructions in "Mounting and aligning the optics on the target machine" in Chapter 4.

For straightness measurements, complete the instructions in "Mounting and aligning optics for X-axis or Y-axis measurements" in Chapter 5.

You are now ready to align the laser beam to the machine's travel path; continue with the next section.

Aligning the laser beam to the machine's travel path

For linear measurements, complete the instructions in "Aligning the laser beam to the machine's travel path for long-range measurements" in Chapter 2 if your measurement is 350 mm (14 inches) or more. If your measurement distance is less than 350 mm (14 inches), follow the instructions in "Aligning the laser beam to the machine's travel path for short-range measurements" in Chapter 2.

For angular measurements, complete the instructions in "Aligning the laser beam to the machine's travel path for short-range measurements" in Chapter 2 regardless of the length of your measurement.

For straightness measurements, complete the instructions in "Aligning the laser beam to the machine's travel path" and "Checking the alignment for beam strength" in Chapter 5.

You are now ready to make a timebase measurement; continue with the next section.

Making the measurement

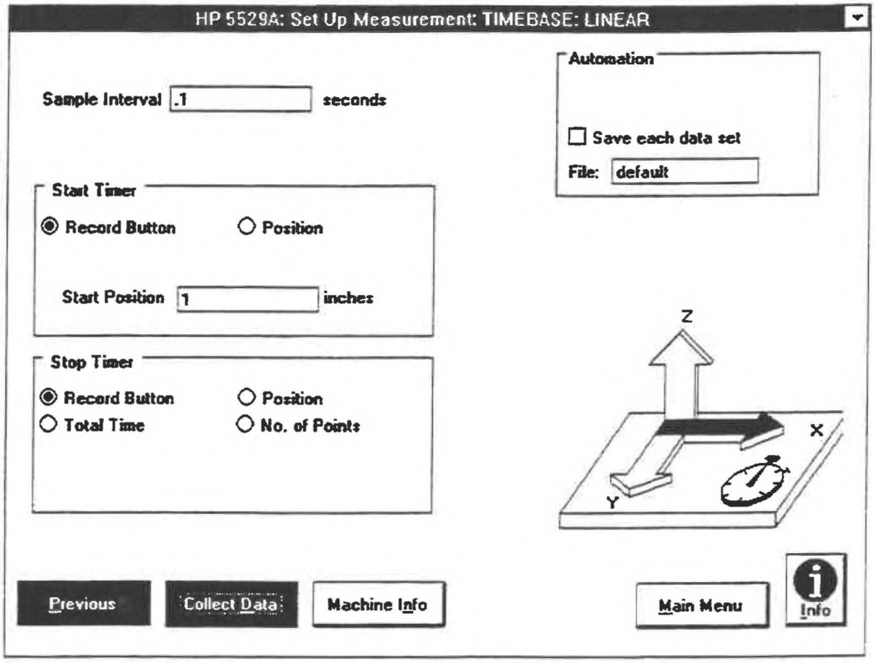
This section explains how to make a timebase measurement. If you are using sensors, make sure they are properly placed and the software is set up properly. (Refer to the *HP 5529A Getting Started Guide* for complete instructions on using the software and the sensors.)

To make a timebase measurement, follow these steps:

1 **Place the moveable optic at its starting position.**

2 **On the Set Up Laser: TIMEBASE screen, select Set Up Meas.**

The Set Up Measurement: TIMEBASE screen is displayed (Figure 3-3).



HP 5529A: Set Up Measurement: TIMEBASE: LINEAR

Sample Interval .1 seconds

Start Timer
● Record Button ○ Position
Start Position 1 inches

Stop Timer
● Record Button ○ Position
○ Total Time ○ No. of Points

Automation
☐ Save each data set
File: default

Figure 3-3. Set Up Measurement: TIMEBASE screen

3 **Complete the fields on the Set Up Measurement: TIMEBASE screen as follows:**

a To change the Sample Interval value, highlight the numbers you want to change and enter the new value.

This field specifies the time between two consecutive samples of laser position. For a slow machine tool movement, make sure the sample interval is long enough to collect an adequate amount of data. For a fast machine tool movement, make sure the sample interval is short enough to capture all changes. If necessary, see the online help to determine the range of values.

b In the Start Timer box, specify the starting conditions from the choices available for your measurement.

Record Button enables you to use either the remote control unit's record button or the Collect Data:

TIMEBASE screen's Start Timer button. Note that there is a slight timing difference between the operation of these two controls. The remote control unit's record button operates the timer with minimal delay since it is connected directly to the axis board containing the timer circuit. The Collect Data: TIMEBASE screen's Start Timer button has a somewhat longer delay because it operates the timer through the software.

You may specify a threshold laser position value that the machine must cross in either direction in order to start the timer and begin collecting data via the Start Position field. When you choose Position, the Collect Data: TIMEBASE screen's timer control button is labeled Arm Timer.

Note Position can only be used for linear measurements.

c In the Stop Timer box, specify the ending conditions from the choices available for your measurement.

Record Button is similar in function to that described for the Start Timer box in step 3b. However, note that the Collect Data: TIMEBASE screen's timer control button is labeled Stop Timer.

Note For very small time intervals, the system may respond more quickly to the remote control unit's record button than to the Collect Data: TIMEBASE screen's Stop Timer button.

Regardless of the Stop Timer condition you selected on the Set Up Measurement: TIMEBASE screen, the remote control unit's record button will always stop a measurement in progress. This is useful in case your specified Stop Timer condition is not met in a timely manner.

Exiting from the Collect Data:TIMEBASE screen will also stop a measurement.

Position is similar in function to that described for the Start Timer box in step 3b. However, note that you use the Stop Position field and that the Collect Data: TIMEBASE screen's timer control button is labeled Stop Timer.

Total time requires you to specify the total time for your measurement in the Stop Position field.

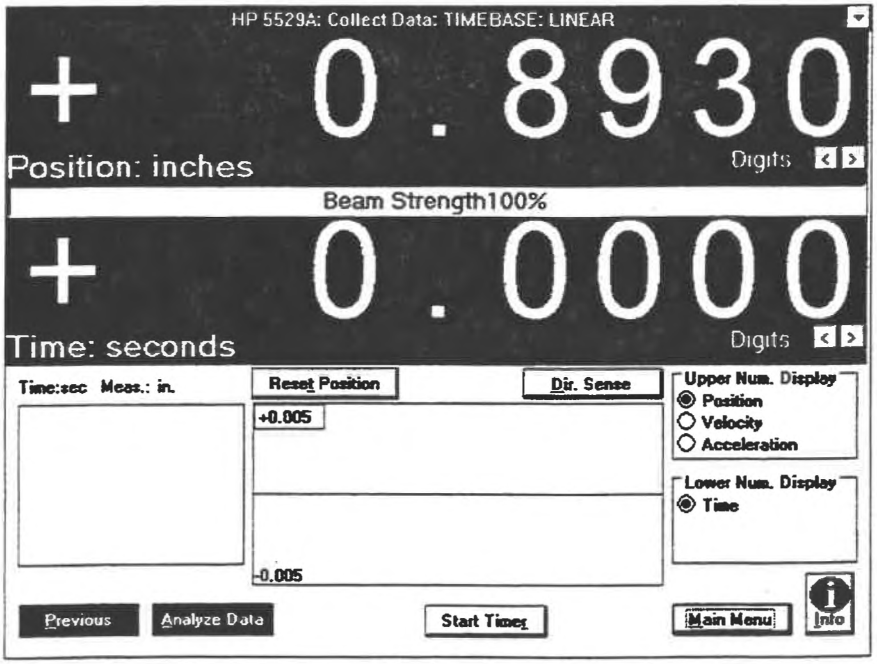
No. of Points requires you to specify the number of position samples to be taken for a complete measurement.

d In the Automation box, you can select Save each data set. This automatically saves data at the end of each complete measurement. Specify the file into which the data will be saved. Refer to the online help for more information. If the specified file already exists, the new data will replace it.

e If you want to display or change information about your machine, select Machine Info.

4 **When you have finished with the Set Up Measurement: TIMEBASE screen, select Collect Data.**

The Collect Data: TIMEBASE screen is displayed (Figure 3-4).



HP 5529A: Collect Data: TIMEBASE: LINEAR

+ 0.8930

Position: inches

Beam Strength100%

+ 0.0000

Time: seconds

Time:sec Meas.: in.

Upper Num. Display
● Position
○ Velocity
○ Acceleration

Lower Num. Display
● Time

Figure 3-4. Collect Data: TIMEBASE screen

5 **Complete the fields on the Collect Data: TIMEBASE screen.**

If necessary, use the online help to complete these fields.

6 **On the Collect Data: TIMEBASE screen, select Reset Position.**

This tells the system that the current position of the reflector is the "zero" point from which all distances will be measured.

If necessary, use the online help to complete the rest of the fields on this screen.

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. The system treats this as a Stop Timer condition. It exits from the Collect Data: TIMEBASE screen to the Analyze Data: TIMEBASE screen and analyzes the data it has taken. You cannot resume the interrupted measurement. Return the machine and measurement optics to the starting position and then restart the measurement.

7 **Select the Start Timer or Arm Timer button or press the record button on your remote control unit.**

This tells the system to clear the graph. The lower numeric display is set to zero. If Record Button was specified for Start Timer on the Set Up Measurement: TIMEBASE screen, the timer and data collection will start immediately. Otherwise, the timer is held off until the specified starting position is reached or crossed. Note that slight timing differences exist between the remote control unit's record button and the Collect Data: TIMEBASE screen's Start Timer or Arm Timer button, as described in step 3b.

The timer stops automatically when the Stop Timer condition specified on the Set Up Measurement: TIMEBASE screen is met.

You can also stop the timer by performing one of the following actions:

- Press the Collect Data: TIMEBASE screen's Stop Timer button or the remote control unit's record button.
- Exit from the Collect Data: TIMEBASE screen.

8 **Select Analyze Data.**

The Analyze Data: TIMEBASE screen is displayed (Figure 3-5).

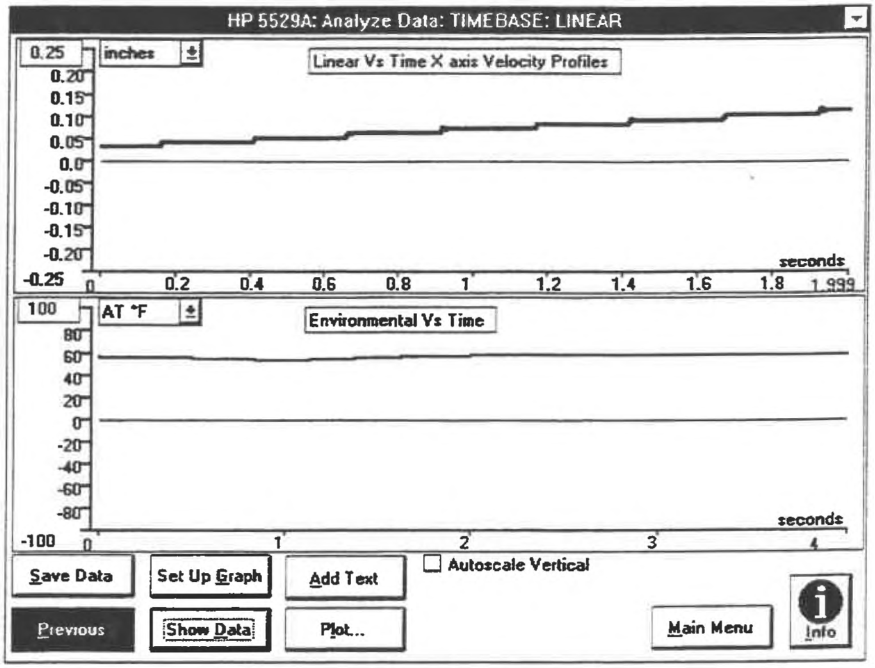

HP 5529A: Analyze Data: TIMEBASE: LINEAR
0.25
inches
Linear Vs Time X axis Velocity Profiles
0.20
0.15
0.10
0.05
0.0
-0.05
-0.10
-0.15
-0.20
-0.25
seconds
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1.999
100
AT °F
Environmental Vs Time
80
60
40
20
0
-20
-40
-60
-80
-100
seconds
0
1
2
3
4
Save Data
Set Up Graph
Add Text
☐ Autoscale Vertical
Previous
Show Data
Plot...
Main Menu
Info

Figure 3-5. Analyze Data: TIMEBASE screen

Continue with the steps presented in “Analyzing timebase measurement data.”

Analyzing timebase measurement data

This section provides information specific to the analysis of timebase measurements data. For general information about using the Analyze Data screen, refer to the *HP 5529A Getting Started Guide* and online help.

Displaying timebase measurement data

Based on how you set up your measurement and what you select on the Set Up Graph: TIMEBASE screen, the Analyze Data: TIMEBASE screen presents laser and environmental data shown on separate graphs and tables.

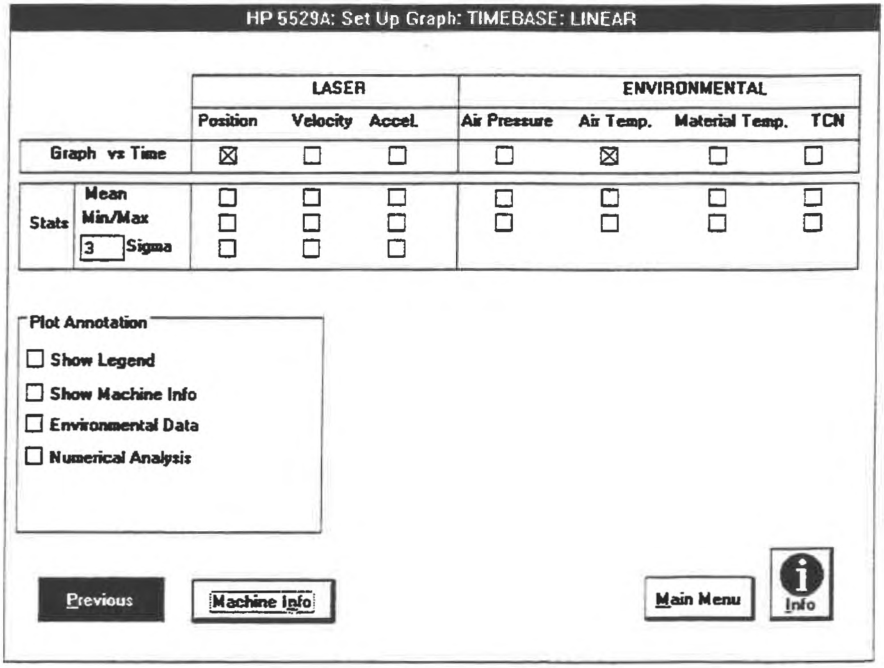
If you are using sensors, the Analyze Data: TIMEBASE screen displays two areas:

- The top half of the screen displays a laser graph. This graph automatically shows the position of the machine tool (represented by a blue trace on color monitors and by a solid line on monochrome monitors). The horizontal axis of the graph always represents time; the vertical axis represents the measurement type (linear, angular, or straightness).
- The bottom half of the screen displays environmental data on a graph.

  Use the Set Up Graph: TIMEBASE screen to specify additional analysis to be plotted on the graphs. For example, to add velocity and acceleration to the laser graph in Figure 3-5, follow these steps:

1 **On the Analyze Data: TIMEBASE screen, select Set Up Graph.**

The Set Up Graph: TIMEBASE screen (Figure 3-6) is displayed.



HP 5529A: Set Up Graph: TIMEBASE: LINEAR

		LASER			ENVIRONMENTAL			
		Position	Velocity	Accel.	Air Pressure	Air Temp.	Material Temp.	TCN
Graph vs Time		☒	☐	☐	☐	☒	☐	☐
Stats	Mean	☐	☐	☐	☐	☐	☐	☐
	Min/Max	☐	☐	☐	☐	☐	☐	☐
	3 Sigma	☐	☐	☐				

Plot Annotation

☐ Show Legend
☐ Show Machine Info
☐ Environmental Data
☐ Numerical Analysis

Figure 3-6. Set Up Graph: TIMEBASE screen

2 **In the LASER box, select one or more of the choices available.**

This tells the system which data to graph. If you want the trace identification to be included on the graph, select Show Legend in the Plot Annotation box.

3 **In the ENVIRONMENTAL box, select the data to graph.**

Environmental data entered manually in the Set Up Laser: TIMEBASE screen is not graphed or displayed in the Show Data Set: TIMEBASE screen.

4 **In the Stats (Statistics) box, select any additional numeric information you want for your laser or environmental data.**

5 **In the Plot Annotation box, select any additional information you want to show on your graph.**

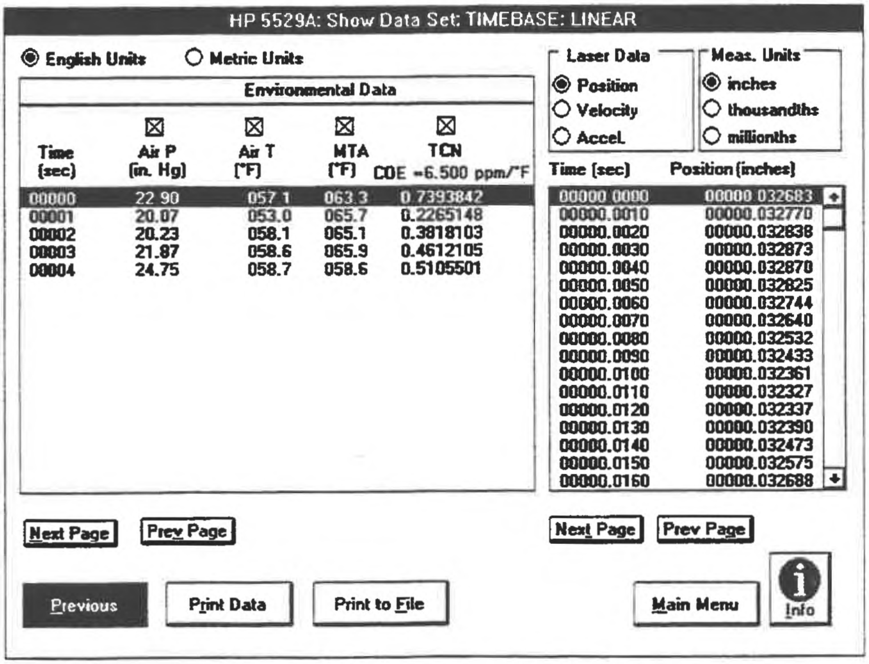
Use the online help for more information about these choices.

6 **If you want to display or change information about your machine, select Machine Info.**

7 **Select Previous to return to the Analyze Data: TIMBEBASE screen.**

8 **To display the timebase measurement data in a table, select Show Data from the Analyze Data: TIMEBASE screen.**

The Show Data Set: TIMEBASE screen is displayed (Figure 3-7).



HP 5529A: Show Data Set: TIMEBASE: LINEAR

● English Units ○ Metric Units

Laser Data: ● Position ○ Velocity ○ Accel.

Meas. Units: ● inches ○ thousandths ○ millionths

Environmental Data

Time (sec)	☒ Air P (in. Hg)	☒ Air T (°F)	☒ MTA (°F)	☒ TCN COE =6.500 ppm/°F
00000	22.90	057.1	063.3	0.7393842
00001	20.07	053.0	065.7	0.2265148
00002	20.23	058.1	065.1	0.3818103
00003	21.87	058.6	065.9	0.4612105
00004	24.75	058.7	058.6	0.5105501

Time (sec)	Position (inches)
00000.0000	00000.032683
00000.0010	00000.032770
00000.0020	00000.032838
00000.0030	00000.032873
00000.0040	00000.032870
00000.0050	00000.032825
00000.0060	00000.032744
00000.0070	00000.032640
00000.0080	00000.032532
00000.0090	00000.032433
00000.0100	00000.032361
00000.0110	00000.032327
00000.0120	00000.032337
00000.0130	00000.032390
00000.0140	00000.032473
00000.0150	00000.032575
00000.0160	00000.032688

Figure 3-7. Show Data Set: TIMEBASE screen

Refer to the online help for more information about using the Show Data Set: TIMEBASE screen. Otherwise, you are finished making the measurement.

Understanding timebase measurement data

When you make timebase measurements with the HP 5529A, keep in mind the following mathematical formulas that express velocity and acceleration:

Velocity is the change in position ($Dx = x_2 - x_1$) per unit time interval ($Dt = t_2 - t_1$), expressed as follows:

$$v_1 = Dx / Dt = (x_2 - x_1) / (t_2 - t_1)$$

On the Analyze Data: TIMEBASE screen, velocity is plotted midway between the position points. For example, the first velocity point v_1 is plotted midway between t_1 and t_2. Note that what you measure with the HP 5529A is the average velocity during a specified time interval.

Acceleration is the change in velocity ($Dv = v_2 - v_1$) per unit time interval ($Dt = t_2 - t_1$), expressed as follows:

$$a_2 = (Dv / Dt) = (v_2 - v_1) / Dt$$

Using the equation for velocity, you can also express acceleration as follows:

$$a_2 = ((x_3 - x_2) - (x_2 - x_1)) / (Dt)^2 = (x_3 - 2x_2 + x_1) / (Dt)^2$$

On the Analyze Data: TIMEBASE screen, acceleration is plotted midway between the velocity points. For example, the first acceleration point a_2 is plotted at t_2.

Note Position may be linear, angular, or straightness. The corresponding velocity and acceleration are linear, angular, or straightness.

4. Angular measurements

4. Angular measurements

4

Angular measurements

Angular measurements

This chapter explains how to make angular measurements at multiple points along a machine's travel path to test for pitch or yaw. Before performing the procedures described in this chapter, you must understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide.* For operating specifications, see Appendix A.

1 Two posts and height adjusters, p/n 10785A
2 Angular reflector, p/n 10771A
3 Angular interferometer, p/n 10770A
4 Two alignment targets, p/n 10767-67001
5 Base, p/n 10784A

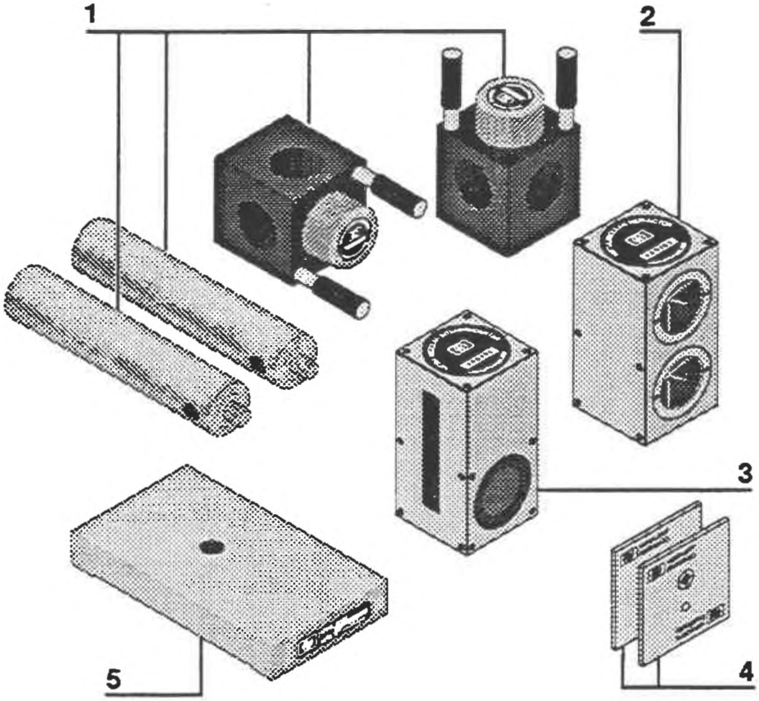


Figure 4–1. Required optics and hardware for angular measurements

Setting up for the measurement

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head, remote control unit, and sensors (if used) to the connectors on the 10886A and 10887A boards installed in the computer.**

The connectors are either on the rear or the side of the computer.

3 **Plug in and turn on all equipment.**

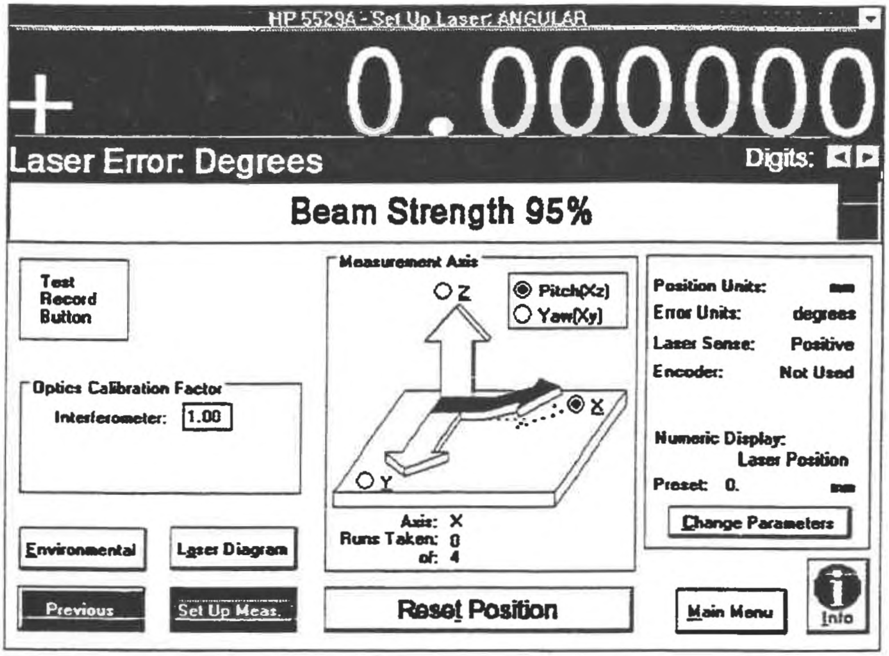
4 **Start the metrology software.**

The Metrology Main Menu is displayed.

5 **On the Metrology Main Menu, select Angular.**

The Set Up Laser: Angular screen (Figure 4–2) is displayed.

Alternately, you can open an existing angular measurement setup file from your database by selecting Recall Data on the Main Menu.


HP 5529A - Set Up Laser: ANGULAR

+ 0.000000

Laser Error: Degrees

Beam Strength 95%

Optics Calibration Factor
Interferometer: 1.00

Measurement Axis
● Pitch(Xz)
○ Yaw(Xy)

Axis: X
Runs Taken: 0
of: 4

Position Units: mm
Error Units: degrees
Laser Sense: Positive
Encoder: Not Used

Numeric Display: Laser Position
Preset: 0. mm

Digits:
Test Record Button
Z
X
Y
Change Parameters
Environmental
Laser Diagram
Previous
Set Up Meas.
Reset Position
Main Menu
Info

Figure 4–2. Set Up Laser: Angular screen

6 Complete the fields on the Set Up Laser: Angular screen.

If necessary, use the online help.

To obtain the greatest accuracy possible, you must account for environmental factors such as ambient temperature and humidity. If you are not using sensors, follow steps 7 through 9 in “Setting up the measurement” in Chapter 2. If you are using sensors, follow the instructions in “Placing and using the sensors” in Chapter 2.

You are now ready to mount and align the optics on the target machine.

Mounting and aligning the optics on the target machine

This section explains how to correctly mount and align the interferometer and reflector on the target machine before making a measurement.

Notes

- If linear optics are already mounted on the target machine, you can install the angular optics by simply changing the optics without changing the mounting hardware (figures 4–3 and 4–4).
- Changes in the reflector's temperature will affect the accuracy of your measurements. To minimize this problem, (1) avoid excessive handling of the reflector, and (2) keep the reflector away from sources of heat and cold, such as air vents.

Mounting the optics

To mount the optics on the target machine, follow these steps:

CAUTION Before mounting the optics or making an angular measurement, be sure the laser head and the target machine are as stable and free of vibration as possible. Movement of the optics, even from slight vibration, reduces the accuracy of your measurement and may cause the receiver on the laser head to lose beam strength during a measurement.

1. **Position the laser head along the axis most suitable for the measurement that you want to make (figures 4–3 and 4–4).**
2. **Adjust the laser head to the approximate height at which you will mount the optics.**
3. **Move the moveable part of the target machine as close as possible to the laser head.**

   This helps prevent the moveable part from hitting the laser head during the alignment and measurement procedures.

4 Determine how to position the optics. See figures 4–3 and 4–4 for sample setups, and use the following guidelines:

- Figures 4–3 and 4–4 show optic setups and positioning for a machine with a table top as the moving part. If the spindle is the moving part, the angular reflector must be mounted on it and the angular interferometer must be mounted on the table between the laser head and the angular reflector.
- Mount one optic where the tool mounts Mount the other optic where the workpiece mounts. Make sure the interferometer is between the reflector and the laser head.
- If you want to measure along an axis perpendicular to the laser beam as it leaves the laser head, mount the interferometer on a part of the machine that remains stationary.

A Measurement along the X-axis

B Measurement along the Y-axis

C Measurement along the Z-axis with the laser beam bent vertically 90° to the optics

****

1 Angular reflector mounted on a height adjuster with a post and base

2 Angular interferometer mounted in a spindle

3 Laser beam

4 Laser head

5 Angular reflector mounted in a spindle

6 Angular interferometer mounted on a height adjuster with a post and base

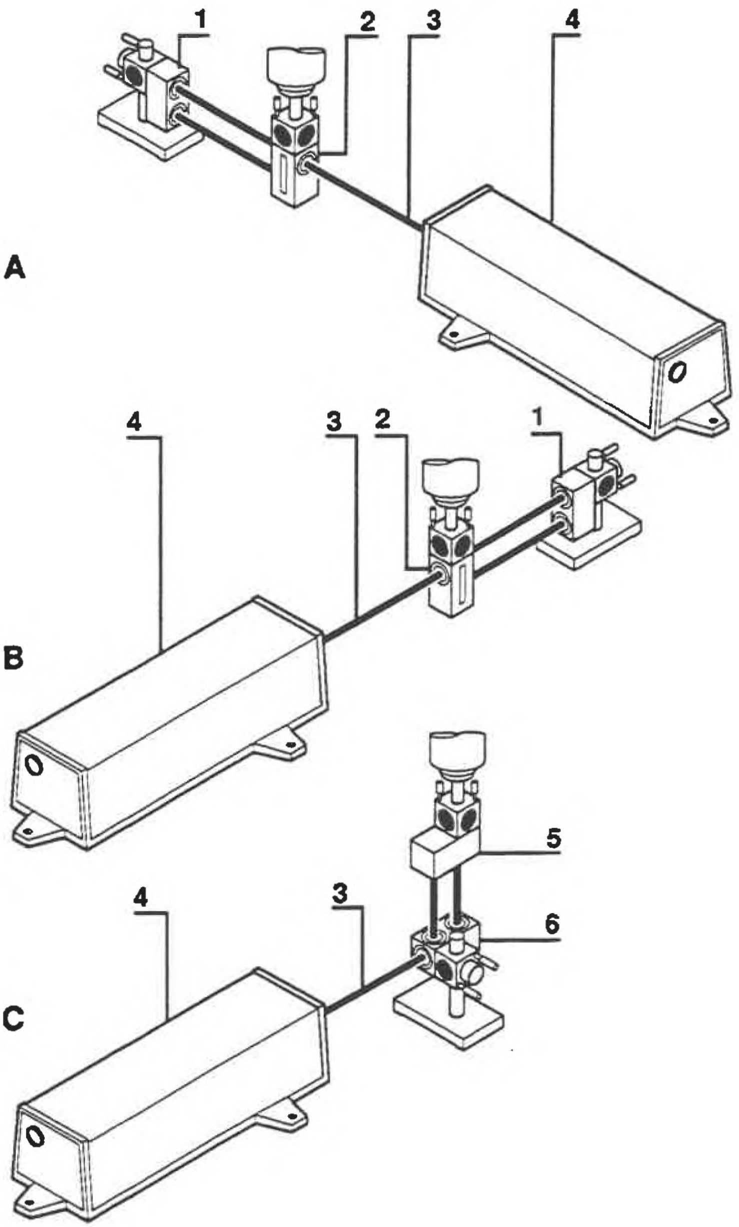


Figure 4–3. Positioning optics for pitch measurements

A Measurement along the Y-axis

B Measurement along the X-axis

C Measurement along the Z-axis with the laser beam bent vertically 90° to the reflector

****

1 Angular reflector mounted on a height adjuster with a post and base

2 Angular interferometer mounted in a spindle

3 Laser beam

4 Laser head

5 Angular interferometer mounted on a height adjuster with a post and base

6 Angular reflector mounted in a spindle

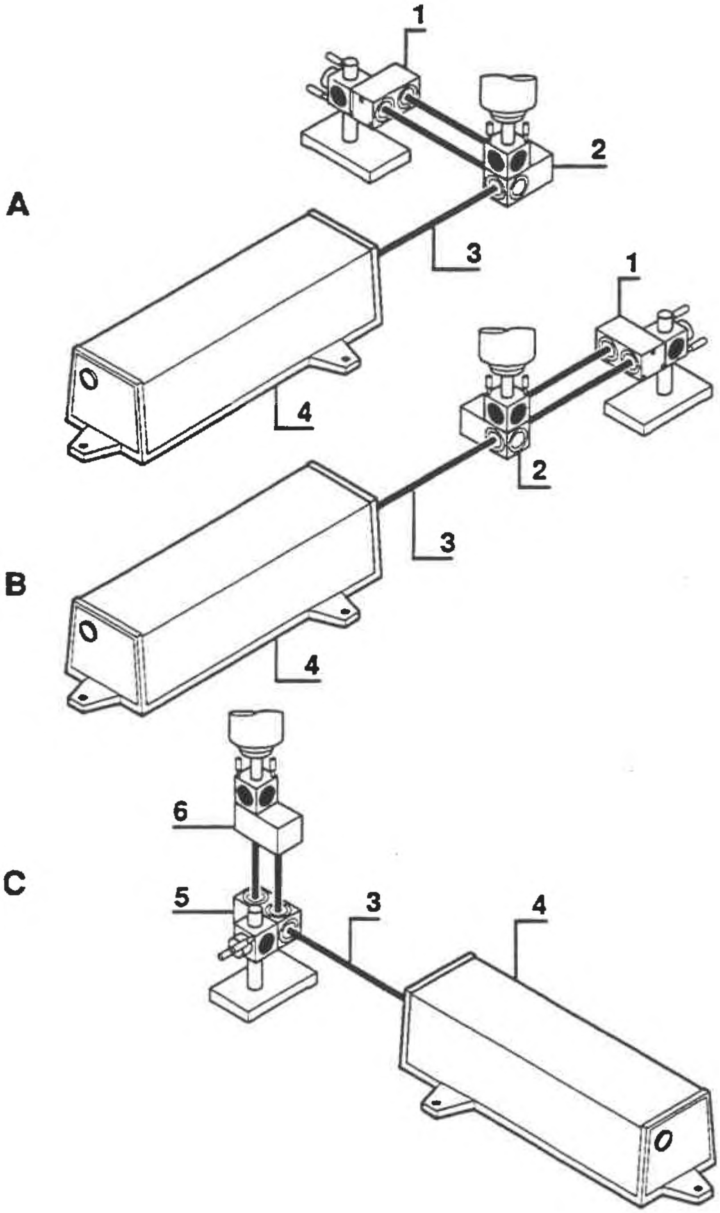


Figure 4–4. Positioning optics for yaw measurements

5 **Assemble the mounting hardware and optic you plan to mount on the table. Follow these steps:**

a Assemble the base, post, and height adjuster (Figure 4–5).

b Attach either the interferometer or the reflector to this assembly.

- If you plan to mount the interferometer on the table, attach the interferometer to this assembly as shown in Figure 4–5 (pitch measurements) or Figure 4–6 (yaw measurements).
- If you plan to mount the reflector on the table, attach the reflector to this assembly as shown in Figure 4–7 (pitch measurements) or Figure 4–8 (yaw measurements).

6 **Mount the optic you assembled in step 5 on the machine's table top.**

Keep the following in mind (see figures 4–3 and 4–4):

- The side of the interferometer with the two openings must face the reflector.
- One of the single openings on the interferometer must face the laser head.

Note If you plan on making a straightness or squareness measurement later, position the height adjuster flush with the top of the post so you can easily change optics.

1 Angular interferometer

2 Height adjuster and post

3 Base

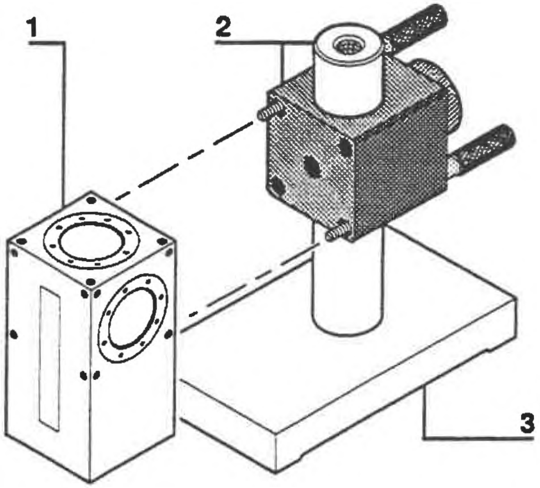


Figure 4–5. Interferometer assembly for pitch measurements along the X-axis or Y-axis

1 Angular interferometer

2 Height adjuster and post

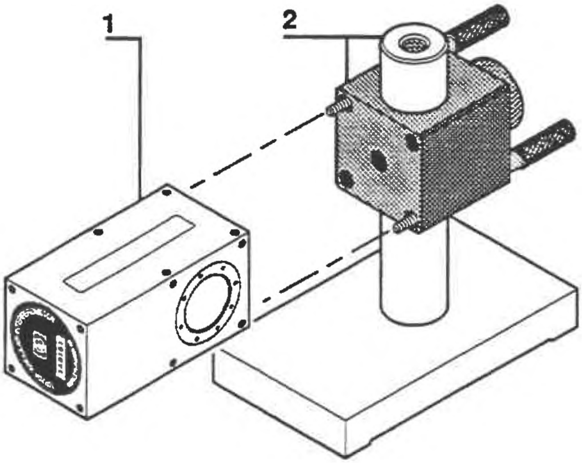


Figure 4–6. Interferometer assembly for yaw measurements along the X-axis or Y-axis

1 Angular reflector

2 Height adjuster and post

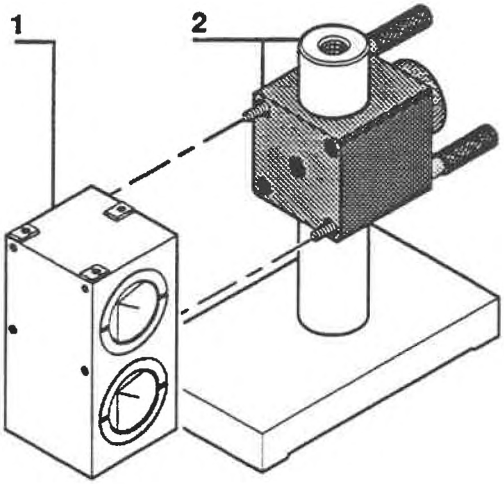


Figure 4–7. Reflector mounting for pitch measurements along the X-axis or Y-axis

1 Angular reflector

2 Height adjuster and post

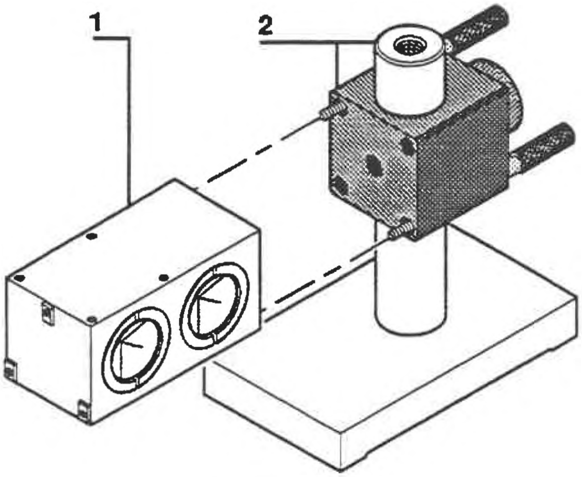


Figure 4–8. Reflector mounting for yaw measurements along the X-axis or Y-axis

In the following steps, you will fasten a post to the height adjuster on the optic you plan to mount in the machine's spindle. (You can then insert the post into the spindle and secure it.) You can connect the post to the height adjuster in one of two ways, as explained in the next step.

7 **Either insert the post into the optics height adjuster and tighten the knurled knob, or remove the large knurled knob from the height adjuster and screw in the post as shown in Figure 4-9.**

The method you choose to mount the optic is up to you.

A Removing the large knurled knob

B Screwing in the post

****

1 Spindle

2 Post

3 Height adjuster

4 Large knurled knob

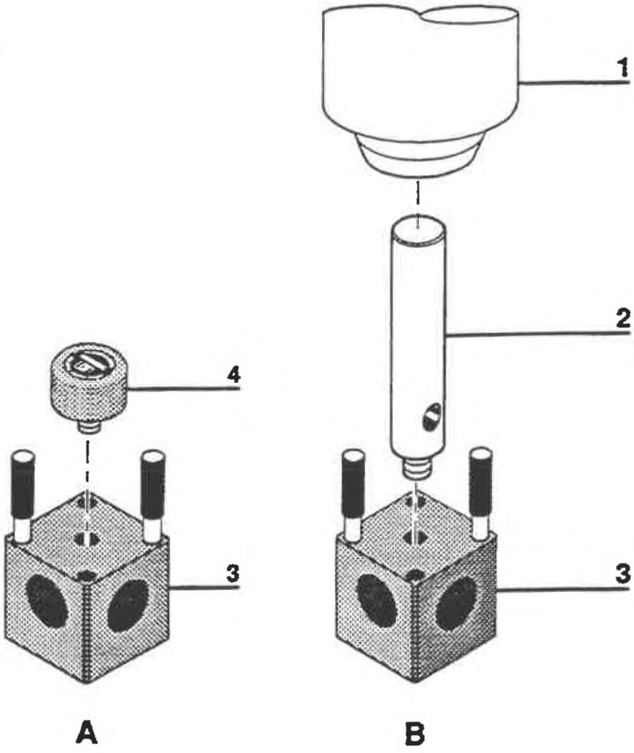


Figure 4–9. Alternate height adjuster mounting

8 **Mount the interferometer or reflector on the spindle as shown in Figure 4–10.**

A Mounting for Z-axis pitch and yaw, or X-axis and Y-axis yaw

B Mounting for X-axis and Y-axis pitch

……

1 Post and height adjuster

2 Angular interferometer or reflector

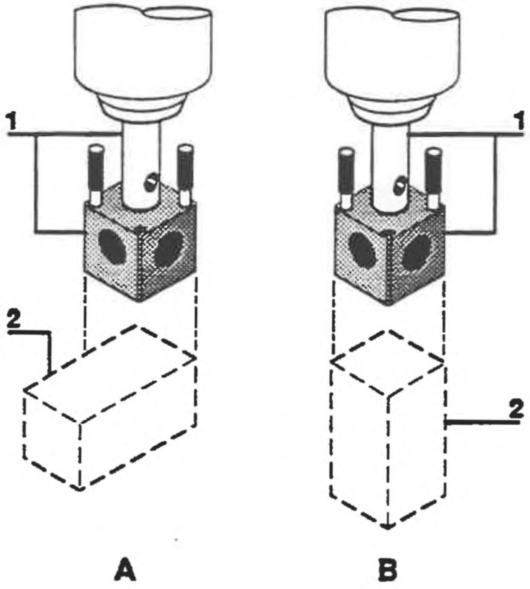


Figure 4–10. Interferometer spindle mounting

Although posts, bases, and height adjusters provide considerable adaptability for mounting optics, there may be some situations when you need added flexibility. Figure 4–11 shows how you can increase adaptability by using additional hardware.

9 **Gently tap each optic with your finger to ensure its mounting is rigid and free of vibration.**

If you feel any vibration, tighten all connections in the mounting.

If you previously made linear measurements using the mounting hardware the angular optics are now on, the optics are already aligned. Since you aligned the laser beam to the machine's travel path prior to making the linear measurement, you can go directly to "Making the measurement" later in this chapter.

1 C-clamp
2 Base
3 Post and height adjuster
4 Angular interferometer or reflector

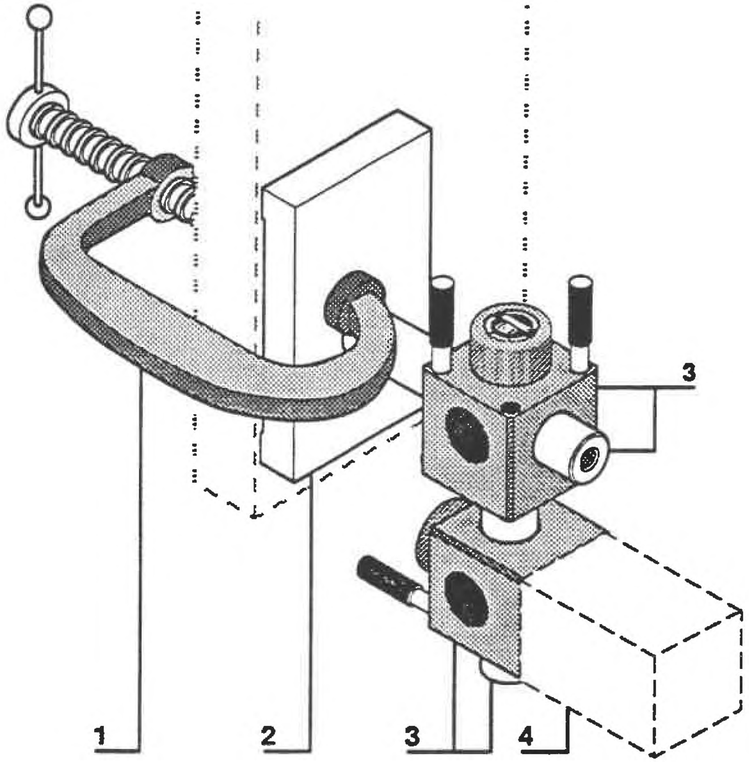


Figure 4–11. Added mounting flexibility

If you did not previously make linear measurements, you must align the optics. Continue with the next section, “Aligning the optics.”

Aligning the optics

To align the optics, follow these steps:

1. **Set the laser head's upper port to the small aperture by turning the upper aperture control (Figure 2–13).**
2. **Rotate the target into position on laser head's lower port by turning the lower aperture control.**
3. **Set the laser head's turret ring to OTHER.**
4. **Attach a target to the interferometer on the side facing the laser head so the target's crosshairs are below the target's hole and the edges of the target line up as evenly as possible with the edge of the interferometer (Figure 4–12).**

A Pitch measurement
B Yaw measurement
C Perpendicular yaw measurement

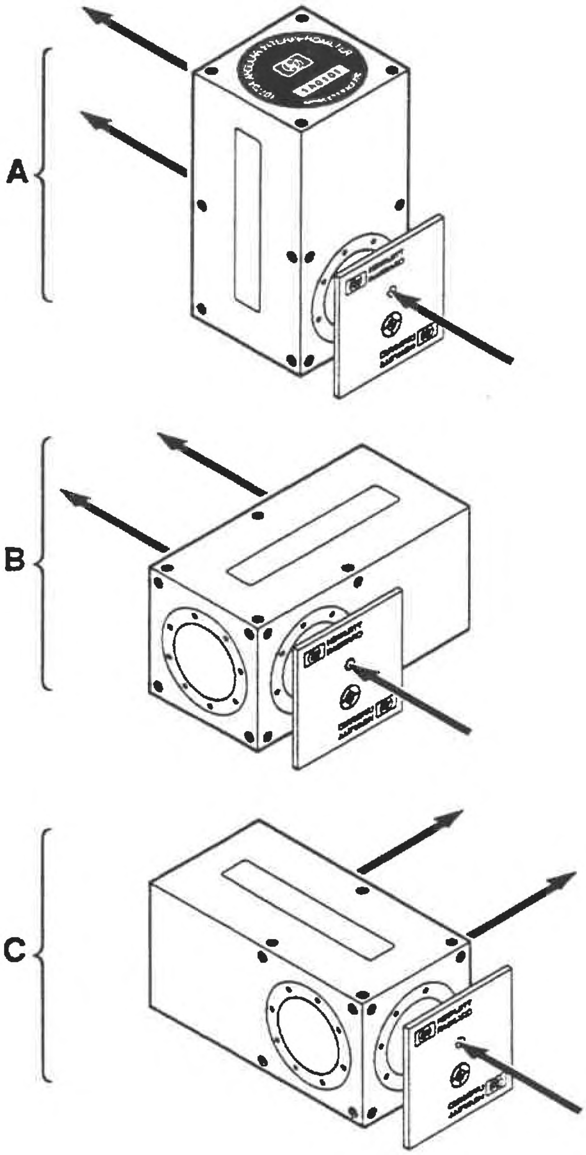


Figure 4–12. Attaching a target to the interferometer

5 **Adjust the interferometer or laser head so that**

- the laser beam enters the hole of the target on the interferometer

- the interferometer is as perpendicular as possible to the beam

To adjust the interferometer up or down, loosen the large knob on the height adjuster, move the interferometer up or down, then tighten the knob. You can also move the interferometer left or right or rotate it left or right.

You can adjust the laser head by rotating it, translating it, or both.

6 **Secure the interferometer to the target machine, maintaining the laser beam's position in the center of the interferometer's target.**

To secure the interferometer to a machine table, use a clamp or similar instrument. Observe the following guidelines when securing the interferometer :

- If you are securing the optic to the spindle, lock the spindle in place.

- If you are securing the optic to a surface such as a machine table, make sure the surface is flat so the optic will not rock.

- When using a clamp to secure the optic, try to cover as much of the optic's base as possible with the clamp so the attachment is secure.

7 **Remove the target from the interferometer.**

8 **Move the reflector as close as possible to the interferometer, and line up the edges of the reflector with the edges of the interferometer.**

In the rest of this chapter, the position of the reflector near the interferometer as described above will be referred to as the "start position."

9 **Adjust the reflector so that**

- its return beam centers on the target covering the laser head's return port
- the reflector is as perpendicular as possible to the beam coming from the interferometer

You can adjust the reflector the same way you adjusted the interferometer.

10 **Secure the reflector to the target machine, maintaining the return beam's position in the center of the laser head's target.**

See the guidelines for securing an optic listed in step 6.

You are now ready to align the laser beam to the laser beam's travel path.

If your measurement distance is less than 350 mm (14 inches), go directly to "Aligning the laser beam to the machine's travel path for short-range measurements."

If your measurement distance is greater than 350 mm (14 inches), continue with the next section, "Aligning the laser beam to the machine's travel path for long-range measurements."

Aligning the laser beam to the machine's travel path for long-range measurements

Follow the instructions in "Aligning the laser beam to the machine's travel path for long-range measurements" in Chapter 2.

You are now ready to make the measurement. Go directly to "Making the measurement."

Aligning the laser beam to the machine's travel path for short-range measurements

Follow the instructions in "Aligning the laser beam to the machine's travel path for short-range measurements" in Chapter 2.

You are now ready to make the measurement. Continue with the next section, "Making the measurement."

Making the measurement

In this procedure, you make manual measurements as you move the machine's moveable part. If you are using sensors, make sure they are properly placed and the software is set up correctly. (Refer to the *HP 5529A Getting Started Guide* for complete instructions on using the software and the sensors.)

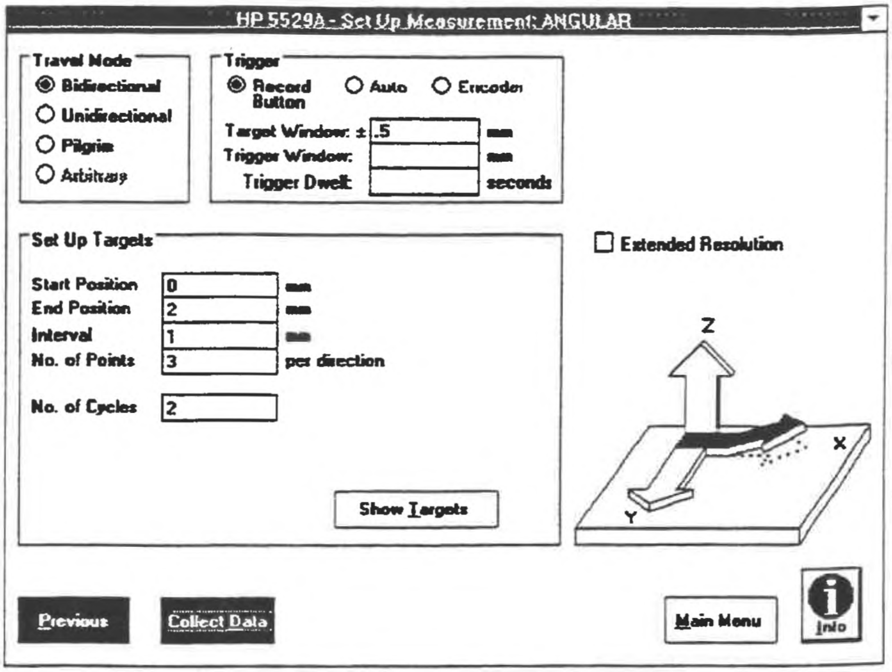
This section explains how to make measurements using the Record button in the software and the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

To make the measurement, follow these steps:

1 **Move the moveable optic so it is at its start position.**

2 **On the Set Up Laser: Angular screen, select Set Up Meas.**

The Set Up Measurement: Angular screen is displayed (Figure 4-13).



HP 5529A - Set Up Measurement: ANGULAR

Travel Mode
- ● Bidirectional
- ○ Unidirectional
- ○ Pilgrim
- ○ Arbitrary

Trigger
- ● Record Button
- ○ Auto
- ○ Encoder

Target Window: ± .5 mm
Trigger Window: mm
Trigger Dwell: seconds

☐ Extended Resolution

Set Up Targets

Start Position 0 mm
End Position 2 mm
Interval 1 mm
No. of Points 3 per direction
No. of Cycles 2

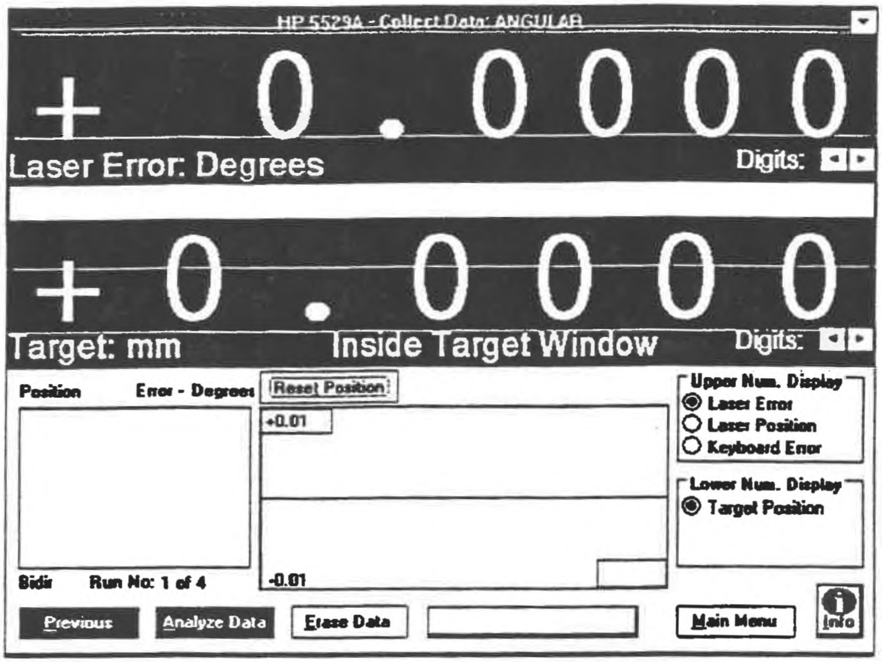
Figure 4–13. Set Up Measurement: Angular screen

3 **Complete the fields on the Set Up Measurement: Angular screen.**

If necessary, use the online help.

4 **Select Collect Data.**

The Collect Data: Angular screen is displayed (Figure 4–14).



HP 5529A - Collect Data: ANGULAR

+ 0.0000

Laser Error: Degrees

+ 0.0000

Target: mm   Inside Target Window

Bidir   Run No: 1 of 4

Upper Num. Display
● Laser Error
○ Laser Position
○ Keyboard Error

Lower Num. Display
● Target Position

Digits:
Digits:
Position
Error - Degrees
Reset Position
+0.01
-0.01
Previous
Analyze Data
Erase Data
Main Menu
Info

Figure 4–14. Collect Data: Angular screen

5 **On the Collect Data: Angular screen, select Reset Position.**

This tells the system that the current position of the reflector is the “zero” point from which all distances will be measured.

If necessary, use the online help to complete the rest of the fields on this screen.

6 **Move the machine's moveable part to the first measurement point.**

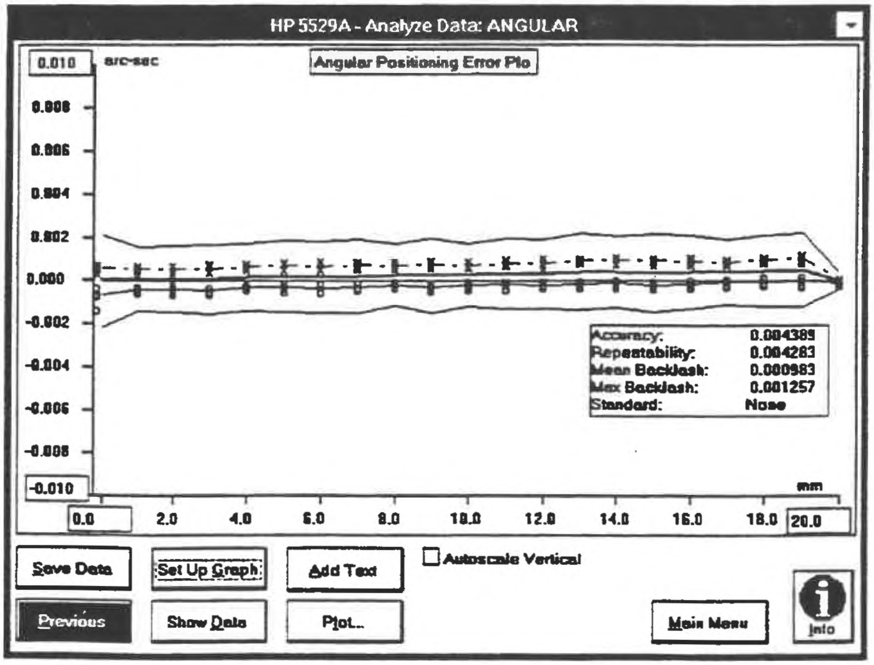
7 **Select Record.**

If you are using the optional remote control unit, press the Record button.

8 **Continue moving the machine’s moveable part to each point and recording measurements until the machine has reached the last measurement position.**

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. Move the moveable optic back to the last point measured, then select Reset Position to reset the system.

After the last measurement is recorded, the Analyze Data: Angular screen is displayed (Figure 4–15).


HP 5529A - Analyze Data: ANGULAR
Angular Positioning Error Plo
arc-sec
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
mm
Save Data
Set Up Graph
Add Text
☐ Autoscale Vertical
Previous
Show Data
Plot...
Main Menu
Info

Accuracy: 0.004389
Repeatability: 0.004283
Mean Backlash: 0.000983
Max Backlash: 0.001257
Standard: None

Figure 4–15. Analyze Data: Angular screen

9 **On the Analyze Data: Angular screen, select Save Data to create or update a data file with the measurement data.**

Refer to the HP *5529A Getting Started Guide* and online help for more information about using this screen. Otherwise, you are finished making the measurement.

MANUAL IDENTIFICATION

Instrument: HP 5529A
Dynamic Calibrator
Measurements Reference Guide

Manual Print Date: February 1996
Manual Part Number: 10747-90019 (English)

ABOUT THIS SUPPLEMENT

The information in this supplement is provided to correct manual errors and to adapt the manual to instruments containing changes after the manual print date.

Change and correction information in this supplement is itemized by page numbers corresponding to the original manual pages. The pages in this supplement are organized in numerical order by manual page number.

HOW TO USE THIS SUPPLEMENT

Insert this title page in front of the title page in your manual.

Perform all changes specified for "All Serials", and all changes through the Series Prefix of your instrument or board.

Insert any complete replacement pages provided into your manual in the proper location. The following replacement pages are included in these manual changes: Chapter 4, A-2

If your manual has been updated according to the last edition of this supplement, you need only perform those changes pertaining to the new series prefix; see List of Effective Pages. New information affecting "All Serials" will be indicated by a "#" in front of the change.

HEWLETT PACKARD

LIST OF EFFECTIVE PAGES

SERIAL PREFIX, SERIAL # OR DATE CODE	PAGES

All Serials .... Chapter 4, A-2

4

Angular measurements

DOCUMENT IS PRINTED AT 90% MEASURE FROM UPPER LEFT CORNER

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Angular measurements

This chapter explains how to make pitch, yaw, or angular position measurements.

Pitch or yaw measurements are made by making angular measurements at multiple points along a machine's (linear) travel path.

Angular position (Angle) measurements are performed by making angular measurements at multiple points as the device being measured is rotated. Angular position measurements may require additional fixturing not required for pitch or yaw measurements. Also, the procedures are different from those for pitch or yaw measurements. Instructions for making an angular position measurement are given later in this chapter, following those for pitch or yaw measurements.

Before performing the procedures described in this chapter, you must understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*. For operating specifications, see Appendix A.

1 Two posts and height adjusters, p/n 10785A

2 Angular reflector, p/n 10771A

3 Angular interferometer, p/n 10770A

4 Two alignment targets, p/n 10767-67001

5 Base, p/n 10784A

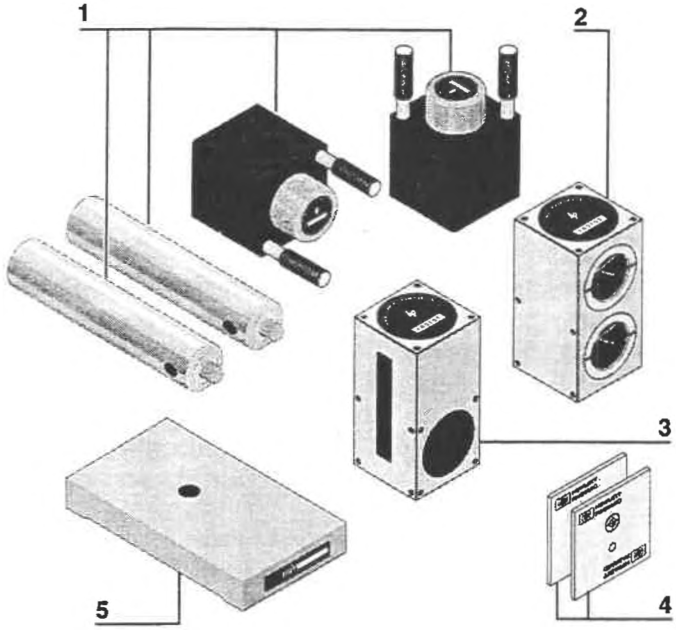


Figure 4–1. Required optics and hardware for angular (pitch or yaw) measurements

Setting up for a pitch or yaw measurement

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head, remote control unit, and sensors (if used) to the connectors on the HP 10886A and HP 10887A boards installed in the computer.**

The connectors are either on the rear or the side of the computer.

3 Plug in and turn on all equipment.

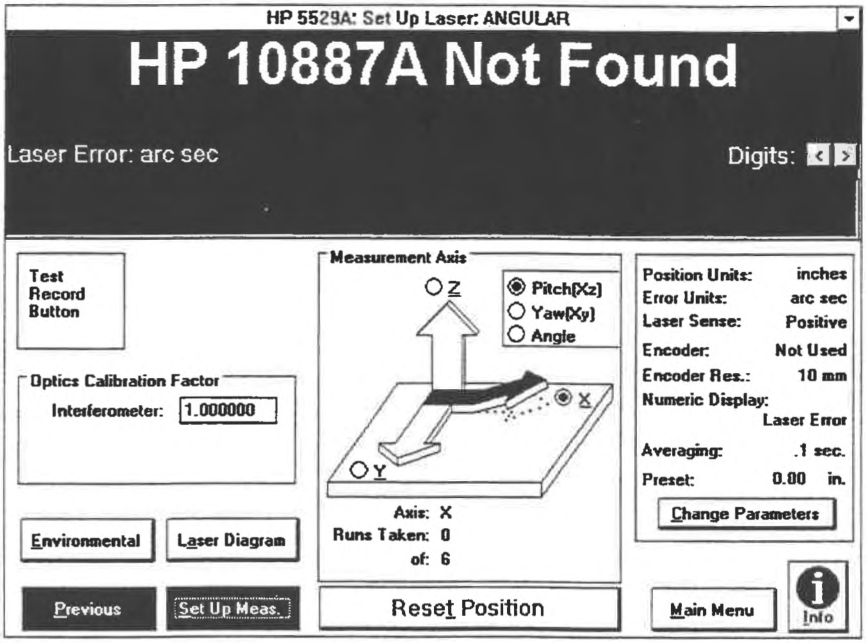
4 Start the metrology software.

The Metrology Main Menu is displayed.

5 On the Metrology Main Menu, select Angular.

The Set Up Laser: Angular screen (Figure 4–2) is displayed.

Alternately, you can open an existing angular measurement setup file from your database by selecting Recall Data on the Main Menu.



HP 5529A: Set Up Laser: ANGULAR

HP 10887A Not Found

Laser Error: arc sec

Optics Calibration Factor
Interferometer: 1.000000

Measurement Axis
● Pitch(Xz)
○ Yaw(Xy)
○ Angle

Axis: X
Runs Taken: 0
of: 6

Position Units: inches
Error Units: arc sec
Laser Sense: Positive
Encoder: Not Used
Encoder Res.: 10 mm
Numeric Display: Laser Error
Averaging: .1 sec.
Preset: 0.00 in.

Digits:
Test Record Button
○ Z
● X
○ Y
Environmental
Laser Diagram
Previous
Set Up Meas.
Reset Position
Change Parameters
Main Menu
Info

Figure 4–2. Set Up Laser: Angular screen

6 **Complete the fields on the Set Up Laser: Angular screen.**

For measurements described in this procedure, select Pitch or Yaw. Instructions for Angle measurements are given later in this chapter.

If necessary, use the online help.

To obtain the greatest accuracy possible, you must account for environmental factors such as ambient temperature and humidity. If you are not using sensors, follow steps 7 through 9 in "Setting up the measurement" in Chapter 2. If you are using sensors, follow the instructions in "Placing and using the sensors" in Chapter 2.

You are now ready to mount and align the optics on the target machine.

Mounting and aligning the optics on the target machine

This section explains how to correctly mount and align the interferometer and reflector on the target machine before making a pitch or yaw measurement.

NOTE

If linear optics are already mounted on the target machine, you can install the angular optics by simply changing the optics without changing the mounting hardware (figures 4–3 and 4–4).

Changes in the reflector's temperature will affect the accuracy of your measurements. To minimize this problem, (1) avoid excessive handling of the reflector, and (2) keep the reflector away from sources of heat and cold, such as air vents.

Mounting the optics

To mount the optics on the target machine, follow these steps:

CAUTION

Before mounting the optics or making an angular measurement, be sure the laser head and the target machine are as stable and free of vibration as possible. Movement of the optics, even from slight vibration, reduces the accuracy of your measurement and may cause the receiver on the laser head to lose beam strength during a measurement.

1 **Position the laser head along the axis most suitable for the measurement that you want to make (figures 4–3 and 4–4).**

2 **Adjust the laser head to the approximate height at which you will mount the optics.**

3 **Move the moveable part of the target machine as close as possible to the laser head.**

This helps prevent the moveable part from hitting the laser head during the alignment and measurement procedures.

4 **Determine how to position the optics. See figures 4–3 and 4–4 for sample setups, and use the following guidelines:**

- Figures 4–3 and 4–4 show optic setups and positioning for a machine with a table top as the moving part. If the spindle is the moving part, the angular reflector must be mounted on it and the angular interferometer must be mounted on the table between the laser head and the angular reflector.

- Mount one optic where the tool mounts. Mount the other optic where the workpiece mounts. Make sure the interferometer is between the reflector and the laser head.

- If you want to measure along an axis perpendicular to the laser beam as it leaves the laser head, mount the interferometer on a part of the machine that remains stationary.

A	Measurement along the X-axis
B	Measurement along the Y-axis
C	Measurement along the Z-axis with the laser beam bent vertically 90° to the optics

****

1	Angular reflector mounted on a height adjuster with a post and base
2	Angular interferometer mounted in a spindle
3	Laser beam
4	Laser head
5	Angular reflector mounted in a spindle
6	Angular interferometer mounted on a height adjuster with a post and base

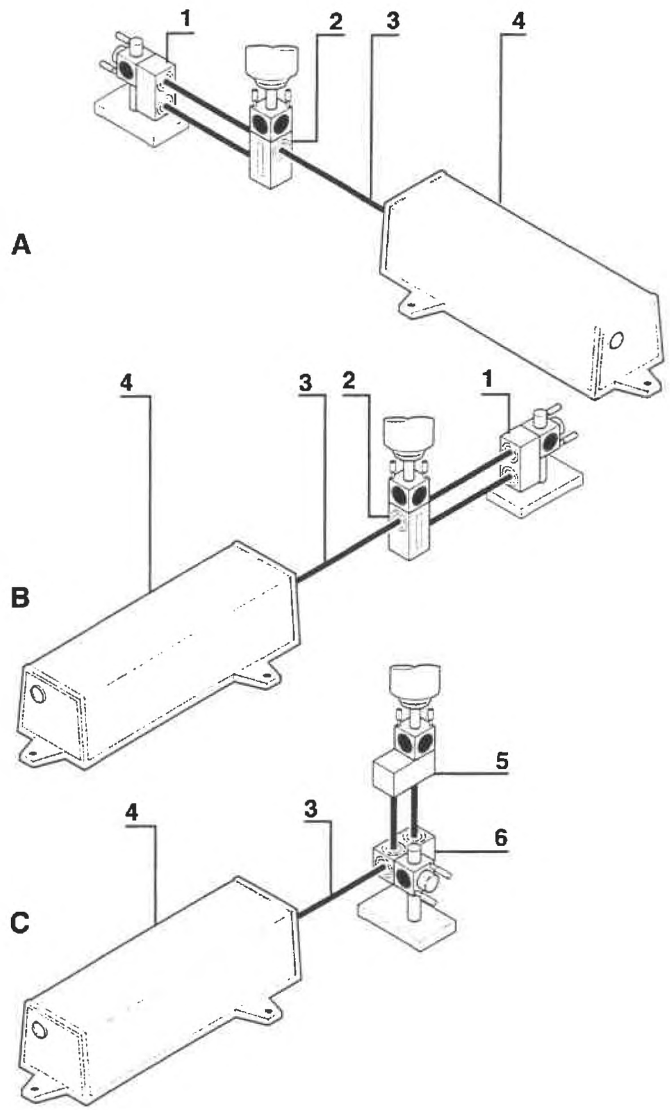


Figure 4–3. Positioning optics for pitch measurements

A Measurement along the Y-axis

B Measurement along the X-axis

C Measurement along the Z-axis with the laser beam bent vertically 90° to the reflector

****

1 Angular reflector mounted on a height adjuster with a post and base

2 Angular interferometer mounted in a spindle

3 Laser beam

4 Laser head

5 Angular interferometer mounted on a height adjuster with a post and base

6 Angular reflector mounted in a spindle

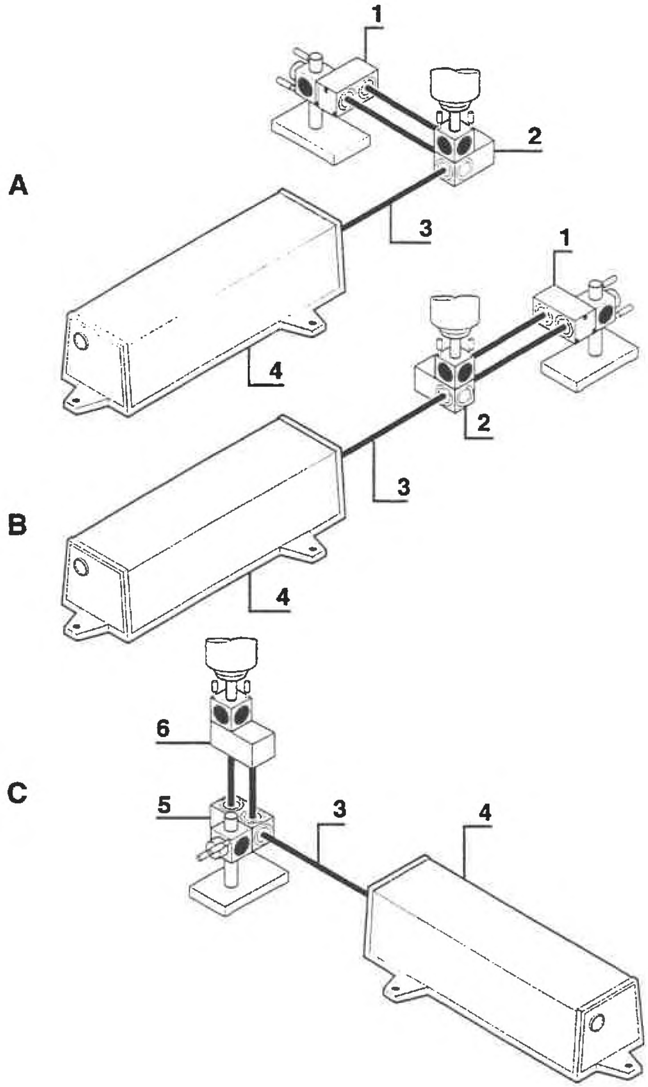


Figure 4–4. Positioning optics for yaw measurements

5 **Assemble the mounting hardware and optic you plan to mount on the table. Follow these steps:**

a Assemble the base, post, and height adjuster (Figure 4–5).

b Attach either the interferometer or the reflector to this assembly.

- If you plan to mount the interferometer on the table, attach the interferometer to this assembly as shown in Figure 4–5 (pitch measurements) or Figure 4–6 (yaw measurements).

- If you plan to mount the reflector on the table, attach the reflector to this assembly as shown in Figure 4–7 (pitch measurements) or Figure 4–8 (yaw measurements).

6 **Mount the optic you assembled in step 5 on the machine's table top.**

Keep the following in mind (see figures 4–3 and 4–4):

- The side of the interferometer with the two openings must face the reflector.

- One of the single openings on the interferometer must face the laser head.

NOTE

If you plan on making a straightness or squareness measurement later, position the height adjuster flush with the top of the post so you can easily change optics.

1 Angular interferometer

2 Height adjuster and post

3 Base

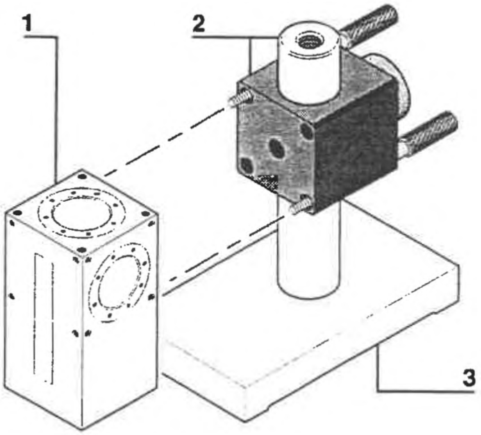


Figure 4–5. Interferometer assembly for pitch measurements along the X-axis or Y-axis

1 Angular interferometer

2 Height adjuster and post

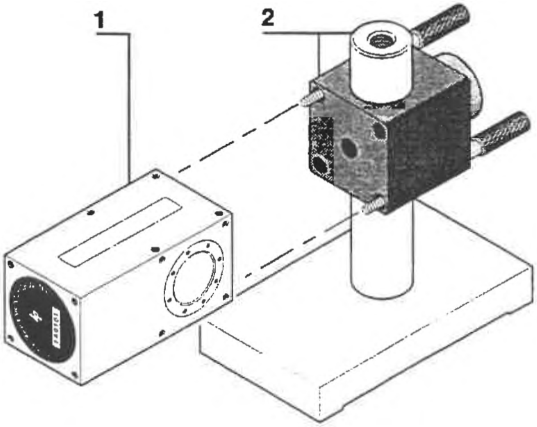


Figure 4–6. Interferometer assembly for yaw measurements along the X-axis or Y-axis

1 Angular reflector
2 Height adjuster and post

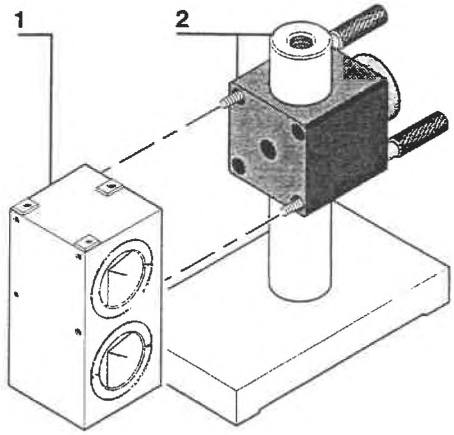


Figure 4–7. Reflector mounting for pitch measurements along the X-axis or Y-axis

1 Angular reflector
2 Height adjuster and post

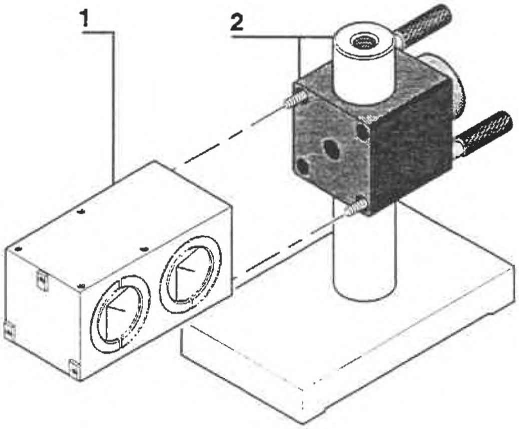


Figure 4–8. Reflector mounting for yaw measurements along the X-axis or Y-axis

In the following steps, you will fasten a post to the height adjuster on the optic you plan to mount in the machine's spindle. (You can then insert the post into the spindle and secure it.) You can connect the post to the height adjuster in one of two ways, as explained in the next step.

7 **Either insert the post into the optics height adjuster and tighten the knurled knob, or remove the large knurled knob from the height adjuster and screw in the post as shown in Figure 4–9.**

The method you choose to mount the optic is up to you.

A Removing the large knurled knob

B Screwing in the post

****

1 Spindle

2 Post

3 Height adjuster

4 Large knurled knob

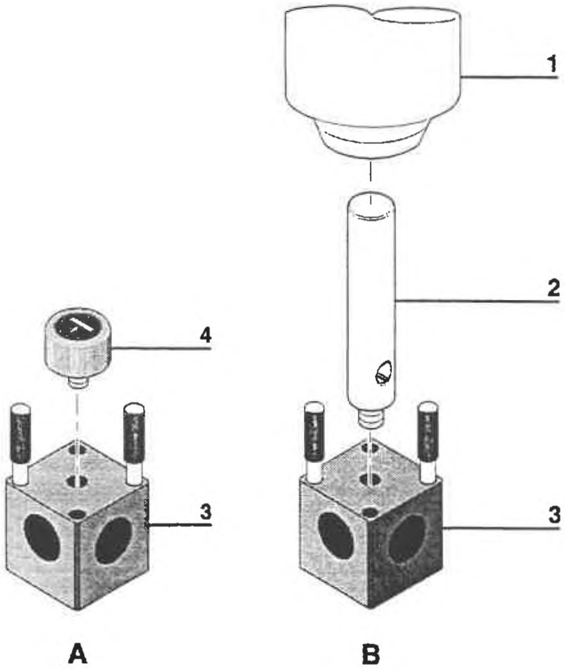
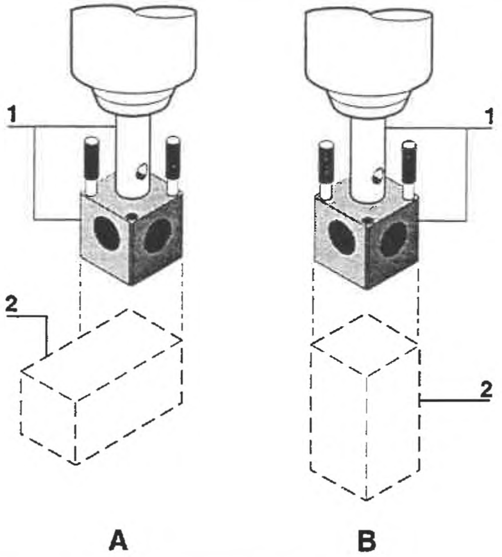


Figure 4–9. Alternate height adjuster mounting

8 Mount the interferometer or reflector on the spindle as shown in Figure 4–10.



A Mounting for Z-axis pitch and yaw, or X-axis and Y-axis yaw

B Mounting for X-axis and Y-axis pitch

****

1 Post and height adjuster

2 Angular interferometer or reflector

Figure 4–10. Interferometer spindle mounting

Although posts, bases, and height adjusters provide considerable adaptability for mounting optics, there may be some situations when you need added flexibility. Figure 4–11 shows how you can increase adaptability by using additional hardware.

9 Gently tap each optic with your finger to ensure its mounting is rigid and free of vibration.

If you feel any vibration, tighten all connections in the mounting.

If you previously made linear measurements using the mounting hardware the angular optics are now on, the optics are already aligned. Since you aligned the laser beam to the machine's travel path prior to making the linear measurement, you can go directly to “Making the measurement” later in this chapter.

1	C-clamp
2	Base
3	Post and height adjuster
4	Angular interferometer or reflector

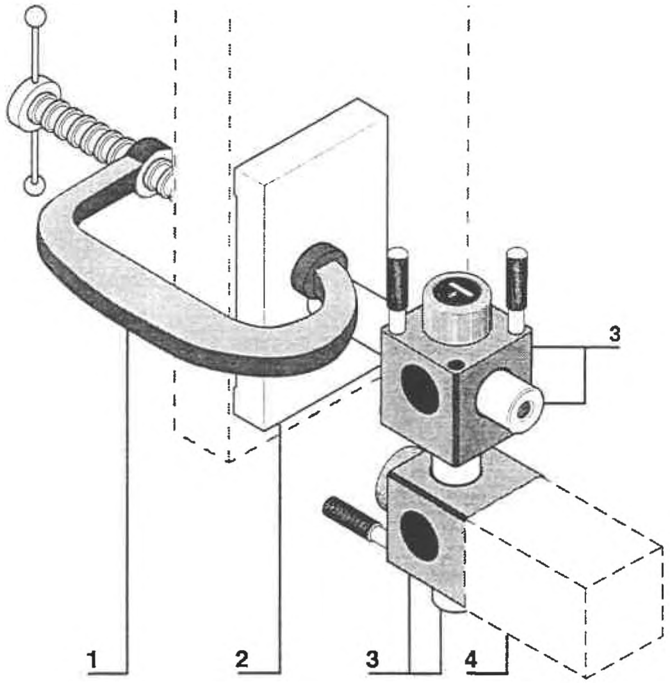


Figure 4–11. Added mounting flexibility

If you did not previously make linear measurements, you must align the optics. Continue with the next section, "Aligning the optics."

Aligning the optics

To align the optics, follow these steps:

1. **Set the laser head's upper port to the small aperture by turning the upper aperture control (Figure 2–13).**
2. **Rotate the target into position on laser head's lower port by turning the lower aperture control.**
3. **Set the laser head's turret ring to OTHER.**
4. **Attach a target to the interferometer on the side facing the laser head so the target's crosshairs are below the target's hole and the edges of the target line up as evenly as possible with the edge of the interferometer (Figure 4–12).**

A Pitch measurement

B Yaw measurement

C Perpendicular yaw measurement

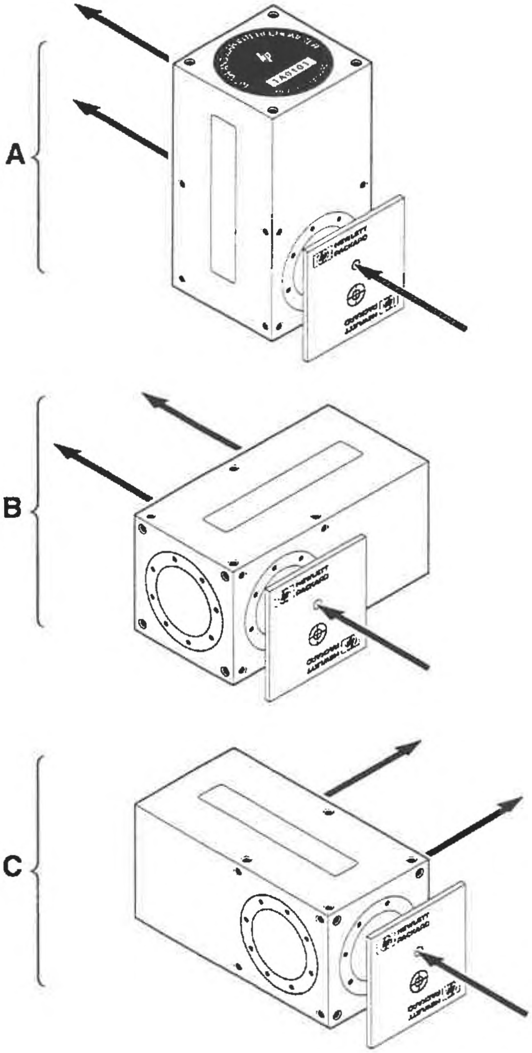


Figure 4–12. Attaching a target to the interferometer

5 **Adjust the interferometer or laser head so that**

- the laser beam enters the hole of the target on the interferometer
- the interferometer is as perpendicular as possible to the beam

To adjust the interferometer up or down, loosen the large knob on the height adjuster, move the interferometer up or down, then tighten the knob. You can also move the interferometer left or right or rotate it left or right.

You can adjust the laser head by rotating it, translating it, or both.

6 **Secure the interferometer to the target machine, maintaining the laser beam's position in the center of the interferometer's target.**

To secure the interferometer to a machine table, use a clamp or similar instrument. Observe the following guidelines when securing the interferometer:

- If you are securing the optic to the spindle, lock the spindle in place.
- If you are securing the optic to a surface such as a machine table, make sure the surface is flat so the optic will not rock.
- When using a clamp to secure the optic, try to cover as much of the optic's base as possible with the clamp so the attachment is secure.

7 **Remove the target from the interferometer.**

8 **Move the reflector as close as possible to the interferometer, and line up the edges of the reflector with the edges of the interferometer.**

In the rest of this chapter, the position of the reflector near the interferometer as described above will be referred to as the "start position."

9 Adjust the reflector so that

- its return beam centers on the target covering the laser head's return port
- the reflector is as perpendicular as possible to the beam coming from the interferometer

You can adjust the reflector the same way you adjusted the interferometer.

10 Secure the reflector to the target machine, maintaining the return beam's position in the center of the laser head's target.

See the guidelines for securing an optic listed in step 6.

You are now ready to align the laser beam to the laser beam's travel path.

If your measurement distance is less than 350 mm (14 inches), go directly to "Aligning the laser beam to the machine's travel path for short-range measurements."

If your measurement distance is greater than 350 mm (14 inches), continue with the next section, "Aligning the laser beam to the machine's travel path for long-range measurements."

Aligning the laser beam to the machine's travel path for long-range measurements

Follow the instructions in "Aligning the laser beam to the machine's travel path for long-range measurements" in Chapter 2.

You are now ready to make the measurement. Go directly to "Making the measurement."

Aligning the laser beam to the machine's travel path for short-range measurements

Follow the instructions in "Aligning the laser beam to the machine's travel path for short-range measurements" in Chapter 2.

You are now ready to make the measurement. Continue with the next section, "Making the measurement."

Making the measurement

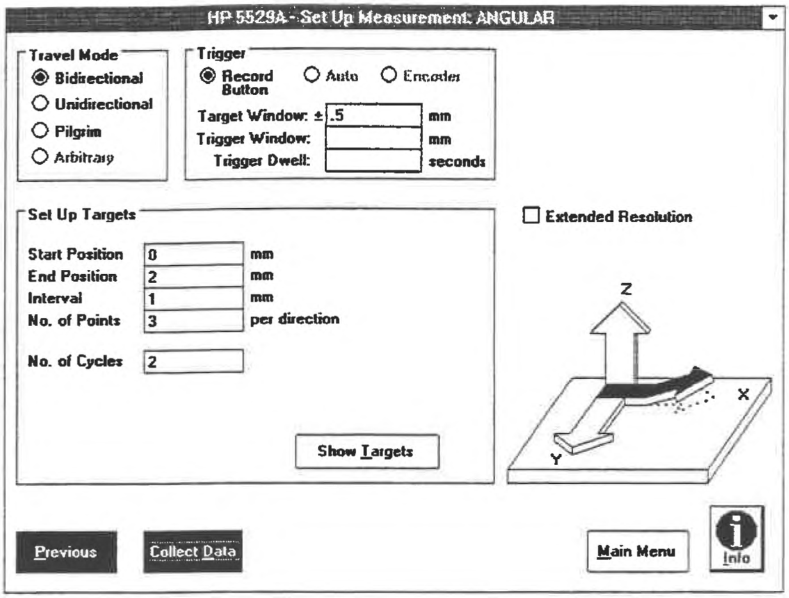
In this procedure, you make manual measurements as you move the machine's moveable part. If you are using sensors, make sure they are properly placed and the software is set up correctly. (Refer to the *HP 5529A Getting Started Guide* for complete instructions on using the software and the sensors.)

This section explains how to make measurements using the Record button in the software and the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

To make the measurement, follow these steps:

1. **Move the moveable optic so it is at its start position.**
2. **On the Set Up Laser: Angular screen, select Set Up Meas.**

   The Set Up Measurement: Angular screen is displayed (Figure 4-13).



HP 5529A - Set Up Measurement: ANGULAR

Travel Mode
● Bidirectional
○ Unidirectional
○ Pilgrim
○ Arbitrary

Trigger
● Record Button ○ Auto ○ Encoder
Target Window: ± .5 mm
Trigger Window: mm
Trigger Dwell: seconds

Set Up Targets
Start Position 0 mm
End Position 2 mm
Interval 1 mm
No. of Points 3 per direction
No. of Cycles 2

☐ Extended Resolution

Figure 4–13. Set Up Measurement: Angular screen

3 **Complete the fields on the Set Up Measurement: Angular screen.**

If necessary, use the online help.

4 **Select Collect Data.**

The Collect Data: Angular screen is displayed (Figure 4–14).

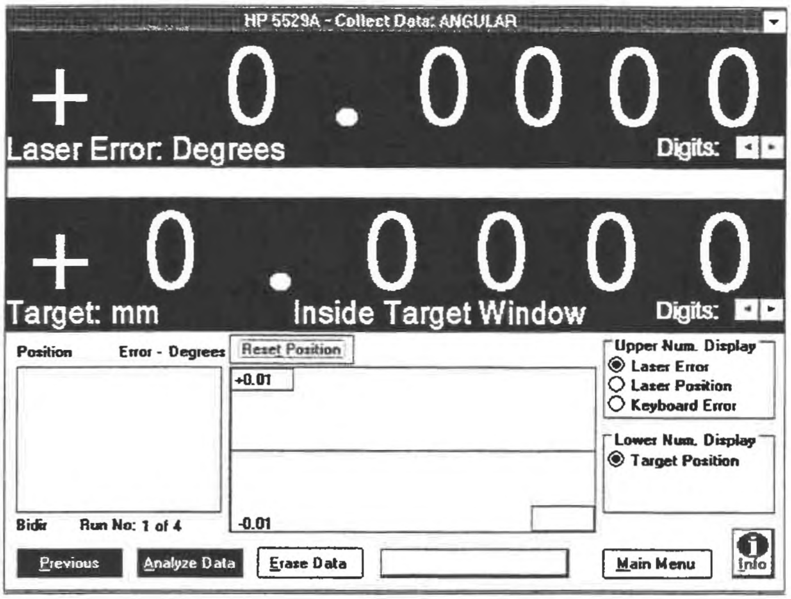

HP 5529A - Collect Data: ANGULAR
+ 0.0000
Laser Error: Degrees
Digits:
+ 0.0000
Target: mm
Inside Target Window
Digits:
Position
Error - Degrees
Reset Position
+0.01
-0.01
Bidir
Run No: 1 of 4
Upper Num. Display
● Laser Error
○ Laser Position
○ Keyboard Error
Lower Num. Display
● Target Position
Previous
Analyze Data
Erase Data
Main Menu
Info

Figure 4–14. Collect Data: Angular screen

5 **On the Collect Data: Angular screen, select Reset Position.**

This tells the system that the current position of the reflector is the “zero” point from which all distances will be measured.

If necessary, use the online help to complete the rest of the fields on this screen.

6 **Move the machine's moveable part to the first measurement point.**

7 **Select Record.**

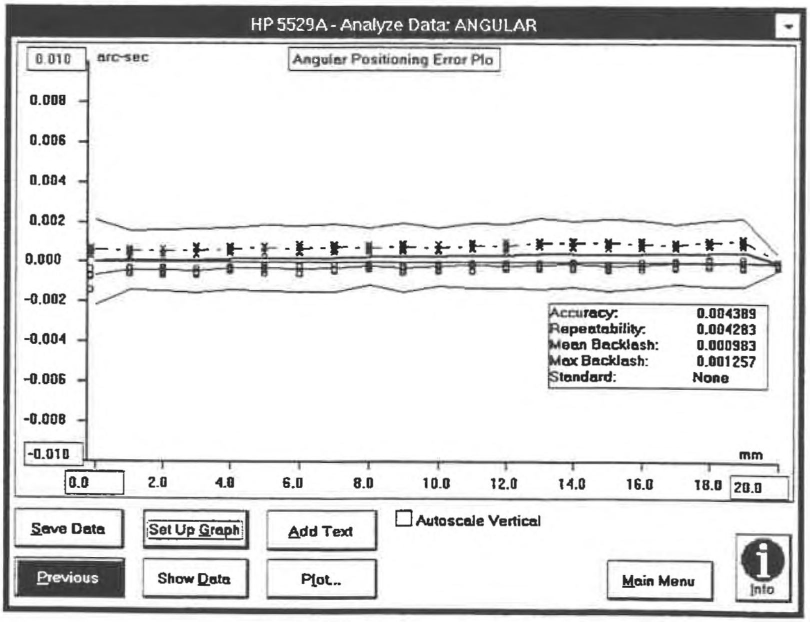
If you are using the optional remote control unit, press the Record button.

8 **Continue moving the machine’s moveable part to each point and recording measurements until the machine has reached the last measurement position.**

NOTE

If at any point the Reset Laser message flashes, the laser beam path has been broken. Move the moveable optic back to the last point measured, then select Reset Position to reset the system.

After the last measurement is recorded, the Analyze Data: Angular screen is displayed (Figure 4–15).


HP 5529A - Analyze Data: ANGULAR
Angular Positioning Error Plo
0.010
arc-sec
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
mm
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Save Data
Set Up Graph
Add Text
☐ Autoscale Vertical
Previous
Show Data
Plot..
Main Menu
Info

Accuracy:	0.004389
Repeatability:	0.004283
Mean Backlash:	0.000983
Max Backlash:	0.001257
Standard:	None

Figure 4–15. Analyze Data: Angular screen

9 **On the Analyze Data: Angular screen, select Save Data to create or update a data file with the measurement data.**

Refer to the HP *5529A Getting Started Guide* and online help for more information about using this screen. Otherwise, you are finished making the measurement.

Angular Position Measurements

An angular position measurement relates angular offset to the angular motion of the device being measured, rather than relating it to the linear motion of the device being measured. Measurement positions are expressed in angular units, rather than linear. One use for the HP 5529A calibrator's angular position measurement capability is to measure the angular positioning accuracy of a rotary table.

The instructions that follow assume that you are using an HP 55290A Angular Position Measurement Kit, shown in Figure 4-17.

The HP 55290A kit, along with the standard HP 5529A calibrator software and hardware, and angular measurement optics (HP 10770A Angular Interferometer and HP 10771A Angular Reflector) are used to make the rotary table calibration.

Figure 4-17 includes a listing of parts provided in:

- the standard HP 55290A Angular Position Measurement Kit,
- the HP 5529A Option 744 Fixturing Kit,
- the HP 55290-67001 Replacement Hardware Kit,
- the HP 55290-67003 Option 744 Hardware Kit.

To order additional or replacement parts, contact your local Hewlett-Packard office or representative.

Principles of Operation

The system described here measures the angular error of an angular position, not total angular rotation. Basic operation during an angular position measurement is simple and straightforward, and is diagrammed in Figure 4-16.

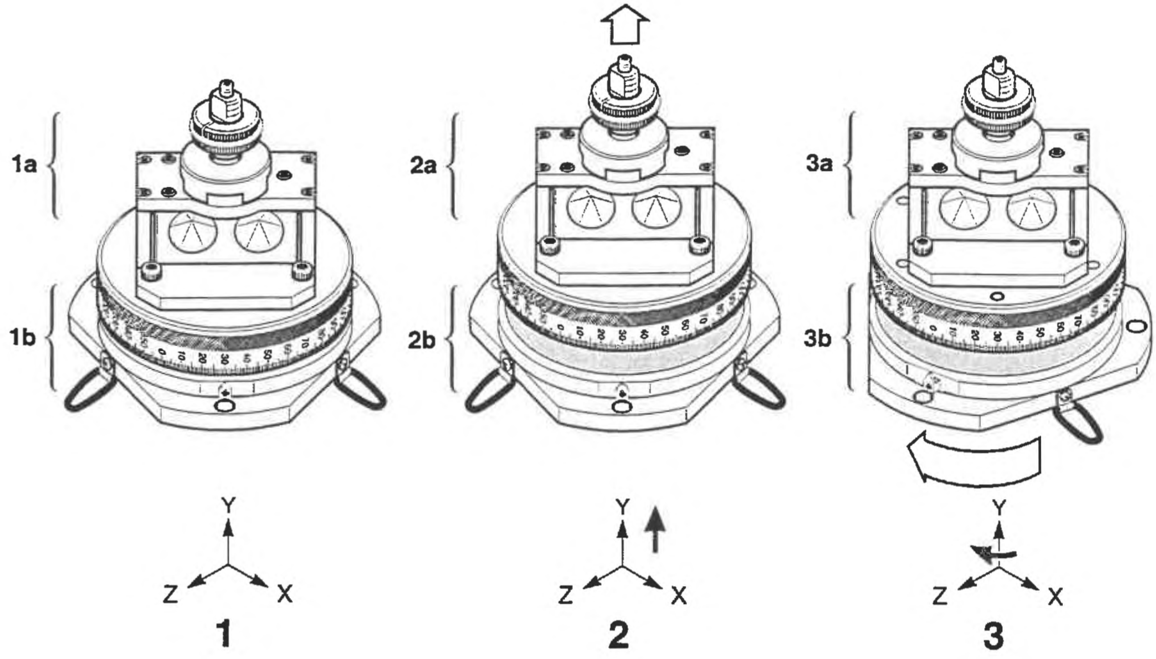
1. The precision index table has a hirth coupling consisting of 360 precision-ground teeth. Its position resolution is one degree, within a ±0.5 arc-second tolerance. The top of the precision index table, which carries the fixture holding the "moveable" optic, is disengaged from its base.

2. The machine part to be calibrated is rotated, turning the precision index table's base with it. The table's top, along with its "moveable" measurement optic is kept from turning by the friction clutch in the fixture.

3. The precision index table's top is re-engaged with its base, and the fixture's clutch is disengaged, allowing best engagement of the two parts of the table. The error measured is the combined error of the table under test and the precision index table.

4. The HP 5529A calibrator is instructed to record a measurement.

These four steps are repeated until all required data has been collected.



1 Table "neutral" position

1a No force on clutch

For the machine control program shown in Figure 4-18, the clutch is depressed 1 mm from this position. This motion ensures appropriate engagement force between the table's top and base.

1b Table top engaged with base

2 Table "disengaged" position

2a Lift top 3 mm to allow base to rotate. First mm lift returns to "neutral" position and re-engages the clutch; remaining 2 mm provides clearance between table's top and base, to allow base to rotate. Set the machine's reference point (relative zero) for this axis after you have performed this lift.

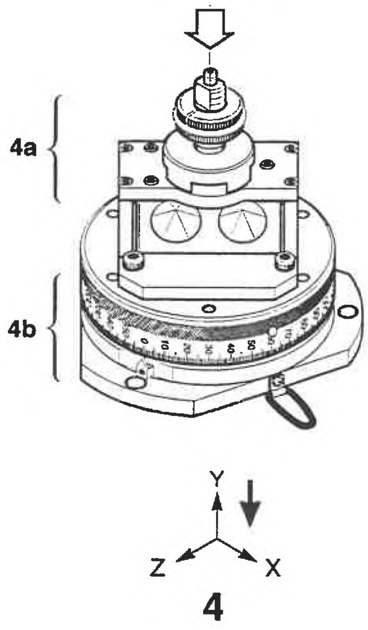
2b Top lifted to allow base to rotate, as described above.

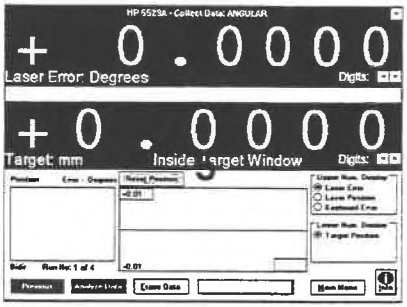
3 Table base rotated

3a Table top has been disengaged, as described in 2a.

3b Machine part being calibrated is rotated, turning the table's base with it.

Figure 4–16. Angular position measurements—principles (Part 1 of 2)




HP 5529A - Collect Data: ANGULAR
+ 0.0000
Laser Error: Degrees
Digits:
+ 0.0000
Target: mm
Inside Target Window
Digits:
-0.01
Run No: 1 of 4
-0.01
Erase Data
Main Menu

4 Table “engaged” position

4a After base has rotated, provide 3.0 mm closing movement to provide sufficient engagement force between top and base.

Allow enough dwell time for measurement data collection before beginning next lift-rotate-lower cycle.

For remaining measurements, cycle controlling axis between this position and relative zero position.

4b Table top engaged with base

5 Instruct HP 5529A calibrator to collect data.

For remaining measurements, repeat step 2 through this step until all data has been collected.

Figure 4–16. Angular position measurements—principles (Part 2 of 2)

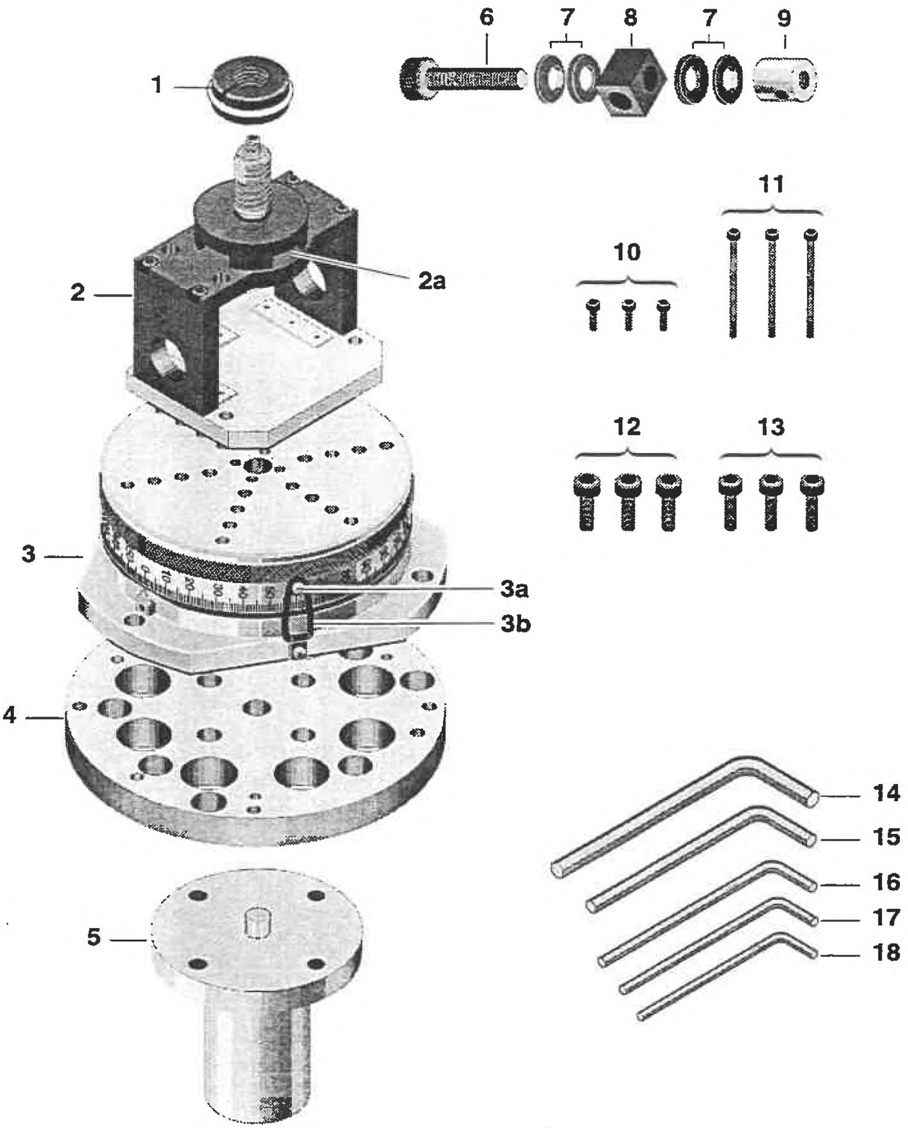

6
7
8
7
9
1
11
10
2a
2
12
13
3
3a
3b
4
14
15
16
17
18
5

Figure 4–17. HP 55290A Angular Position Measurements Kit—(Part 1 of 4)

Ref	HP Part Number	Description	Quantity in HP 55290A	Quantity in HP 55290A Option 744	Quantity in HP 55290-67001	Quantity in HP 55290-67003
1	55290-67002	Kit, nut, break-away	2			
2	no part number	Fixture, Angle Position Measurement	1			
2a	55290-80001	Washer, clutch	1		1	
3	55290-80004	Rotary table	1			
3a	55290-20209	Standoff	3			
3b	0905-1439	O-ring, black	3		3	
4	55290-20211	Adapter plate	1			
5	55290-20210	Flanged shaft	1			
6	0515-2803	Socket-head cap screw, M10 × 40 mm	2		2	
7	3050-1904	Washer set, spherical	2		2	
8	55290-20218	Adapter	1			
9	10768-20213	Post-stub	1			
10	0515-1321	Screw, socket head, cap, M3 × 10 mm	6		6	
11	0515-2802	Socket-head cap screw, M3 × 45 mm	6			
12	3030-0647	Socket head cap screw, 1/4-20 × 5/8 inch	10		10	
13	3030-0870	Screw, socket head, cap, #10-32 × 5/8 inch	6		6	
14	8710-2326	Key, hex, 8 mm	1		1	
15	8710-1452	Key, hex, 6 mm	1		1	
16	8710-0098	Key, hex 3/16-inch	1		1	
17	8710-0056	Hex key, 5/32-inch	1		1	
18	8710-1181	Key, hex, 2.5 mm	1		1	
19	---	not used				
20	---	not used				

Figure 4–17. HP 55290A Angular Position Measurements Kit—(Part 2 of 4)

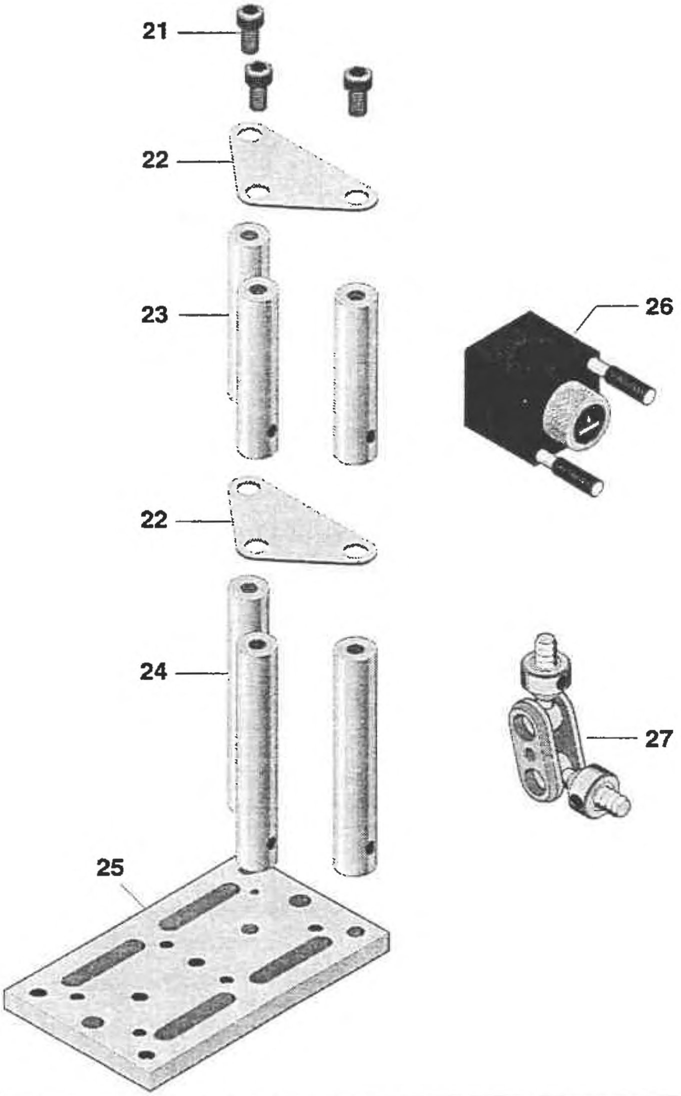

21
22
23
26
22
24
27
25

Figure 4–17. HP 55290A Angular Position Measurements Kit—(Part 3 of 4)

Ref	HP Part Number	Description	Quantity in HP 55290A	Quantity in HP 55290A Option 744	Quantity in HP 55290-67001	Quantity in HP 55290-67003
21	0515-2819	Socket-head cap screw, M10 × 10 mm		6		6
22	10744-00001	Gusset		2		2
23	10776-20008	Post-medium		3		3
24	10785-20005	Post-long		1		3
25	10768-20214	Base-large		1		1
26	For replacement, order HP 10785A	Height Adjuster		1		1
27	10768-60203	Flexible ball joint assembly		1		1

Figure 4–17. HP 55290A Angular Position Measurements Kit—(Part 4 of 4)

Procedure—summary

The angular position measurement procedure has the major activities listed below.

1. Program the machine you will be calibrating.
2. Initially set up the computer and laser head.
3. Mount and align the precision index table
4. Choose and mount the moveable optic.
5. Mount the fixed optic.
6. Align the laser beam to the measurement path.
7. Make the measurement.

Programming the machine to be calibrated

Because of the variety of controllers, it is not possible to present specific instructions for any particular one here. Apply the information presented here to your measurement situation.

Before you install hardware on your machine, you should program the machine to perform the basic movements it will be doing during the measurement. A description of the measurement steps is provided above.

The example program in Figure 4-18, below, assumes that the machine's relative zero was set with the machine holding the measurement fixture and the top of the precision index table in the position that allows the base of the table to rotate independently from the top. This position is 2 mm above the "neutral" position. Refer also to Figure 4-16, above. The example program:

1. Starts from relative zero position set for your measurement, with the precision index table's top lifted to allow clearance for its base to rotate independently.

2. Rotates the table's base the number of degrees you specify.

3. Engages the table's top and base, by lowering the top 3 mm. Feed rate and clamping force during engagement are important.

   The feed rate during engagement is specified. Too slow a feed rate may result in poor engagement repeatability. Too fast a feed rate may damage measurement hardware or cause vibrations in the setup.

   The correct clamping force is provided when the clutch is forced 1 mm below its "neutral" position.

4. Dwells at the engaged position for the time specified, to allow the HP 5529A calibrator to collect data.

5. Lifts the top of the precision index table 3 mm, to completely disengage it from the table's base.

NOTES

This example program does not include setting the relative zero position, which you must do after you finish installing the measurement hardware.

The measurement fixture clutch is designed to apply the desired clamping force when the clutch control shaft has been pressed 1 mm in (down) from its “neutral” position.

The precision index table requires a lift (up) of 2 mm from the measurement fixture clutch’s “neutral” position. This program example assumes that you have set the Z-axis reference with that lift performed; that is, the Z-axis reference position is with the top of the precision table 2 mm above its neutral position.

This example program does not automatically cycle.

```
0103;               / Program ID (name or number)
    •
    •
    •
G01F10000.;         / Degrees per minute. See "Additional Notes," below.
    •
    •
B30.0;              / Rotate B axis 30 Degrees
    •
G91G1F2000.Z-       / Move Z axis incrementally to engage HP 55290A fixture and
3.0;                precision index table in measurement position. See "Additional
                    Notes," below.
    •
    •
G04P2000.;          / Dwell 2.0 seconds
    •
    •
M08;                / Any  "M" function to trigger laser reading when available. (M08
                    = coolant "on")
M09;                / Coolant "off"
G91G0Z3.0           / Move Z axis incrementally to clear for B-axis rotation
M99;                / Return to beginning
%
```

Additional Notes:

G01 or G1 = Interpolate linearly—requires feed rate value

Fxx = Feed rate

Figure 4-18. Machine control program

Initial setup of computer and laser head

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this procedure. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head, remote control unit, and sensors (if used) to the connectors on the HP 10886A and HP 10887A boards installed in the computer.**

The connectors are either on the rear or the side of the computer.

3 **Plug in and turn on all equipment.**

4 **Start the metrology software.**

The Metrology Main Menu is displayed.

5 **On the Metrology Main Menu, select Angular.**

The Set Up Laser: ANGULAR screen is displayed.

Alternatively, you can open an existing angular measurement setup file from your database by selecting Recall Data on the Main Menu.

6 **Complete the fields on the Set Up Laser: ANGULAR screen.**

Select Angle. The display changes to that shown in Figure 4-19. (Instructions for Pitch or Yaw measurements are given earlier in this chapter.)

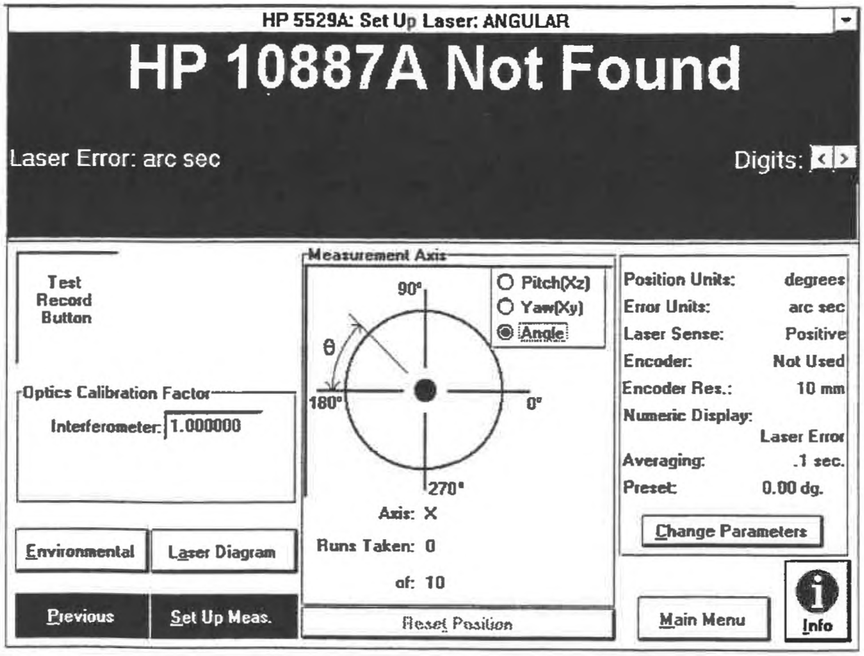
If necessary, use the HP 5529A calibrator's online help.

To obtain the greatest accuracy possible, you must account for environmental factors such as ambient temperature and humidity. If you are not using sensors, follow steps 7 through 9 in "Setting up the measurement" in Chapter 2. If you are using sensors, follow the instructions in “Placing and using the sensors” in Chapter 2.

NOTE

Changes in the interferometer’s temperature will affect the accuracy of your measurements. To minimize this problem, (1) avoid excessive handling of the interferometer, and (2) keep the interferometer away from sources of heat and cold, such as air vents.

You are now ready to mount and align the precision index table and optics on the target machine.


HP 5529A: Set Up Laser: ANGULAR

HP 10887A Not Found

Laser Error: arc sec

Optics Calibration Factor
Interferometer: 1.000000

Measurement Axis
○ Pitch(Xz)
○ Yaw(Xy)
● Angle

Axis: X
Runs Taken: 0
of: 10

Position Units: degrees
Error Units: arc sec
Laser Sense: Positive
Encoder: Not Used
Encoder Res.: 10 mm
Numeric Display: Laser Error
Averaging: .1 sec.
Preset: 0.00 dg.

Digits:
Test Record Button
90°
180°
0°
270°
θ
Environmental
Laser Diagram
Previous
Set Up Meas.
Reset Position
Change Parameters
Main Menu
Info

Figure 4–19. Set Up Laser: ANGULAR screen

Mounting and aligning the precision index table on the target machine

This section explains how to correctly mount and align the precision index table on the target machine before making an angular position (Angle) measurement.

Mounting and aligning on a rotary table

NOTE We expect that most installations will require use of the adapter plate. If your rotary table already has mounting holes that allow proper centering of the precision index table, you do not need to use the adapter plate.

1. **Fasten the adapter plate to your machine's rotary table.** (See Figure 4-20.)

2. **Center the adapter plate on the rotary table's rotation axis.**

3. **Remove the locking ring at the bottom of the precision index table.** (See Figure 4-22.)

4. **Separate the precision index table's top and base and inspect their hirth coupling teeth for cleanliness. If necessary, clean the teeth. A procedure for cleaning the hirth coupling teeth is given in the Maintenance portion of this chapter.**

5. **Rejoin the precision index table's top and base and use the locking loops to hold them together.** (See Figure 4-22.)

6. **Fasten the precision index table to the adapter plate.** (See Figure 4-20.)

7. **Center the precision index table within 25.4 µm (0.001 inch) on your machine's rotary table rotation axis.**

8. **Go to "Choosing the moveable optic" below.**

1	Socket-head cap screw, 1/4 - 20 × 5/8-inch
2	Precision index table
3	Adapter plate
4	Rotary table to be calibrated
5	Locking loop(s)

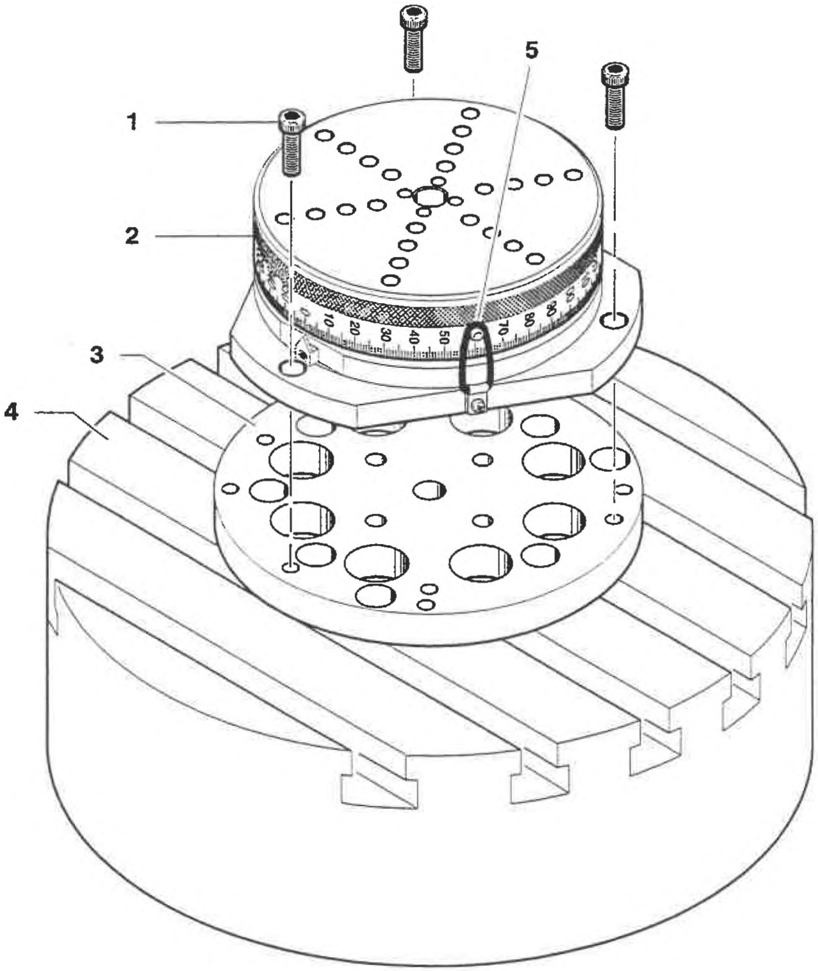

5
1
2
3
4
0
10
20
30
40
50
60
70
80
90

Figure 4-20. Mounting on a rotary table

Mounting and aligning on a machining center

See Figure 4-21.

1. **Fasten the adapter plate to the flanged shaft.** (See Figure 4-21.)
2. **Insert the flanged shaft into your machine's workpiece spindle.**
3. **Use the locking loops to hold the precision index table top and base together.** (See Figure 4-22.)
4. **Remove the locking ring at the bottom of the precision index table.** (See Figure 4-22.)
5. **Fasten the precision index table to the adapter plate.** (See Figure 4-21.)
6. **Center the precision index table within 25.4 µm (0.001 inch) on your machine's workpiece spindle rotation axis.**

1	Flanged shaft
1a	To machine rotary axis being calibrated
2	Adapter plate
3	Socket-head cap screw, 1/4 - 20 x 5/8 inch
4	Precision index table
5	Locking loop(s)

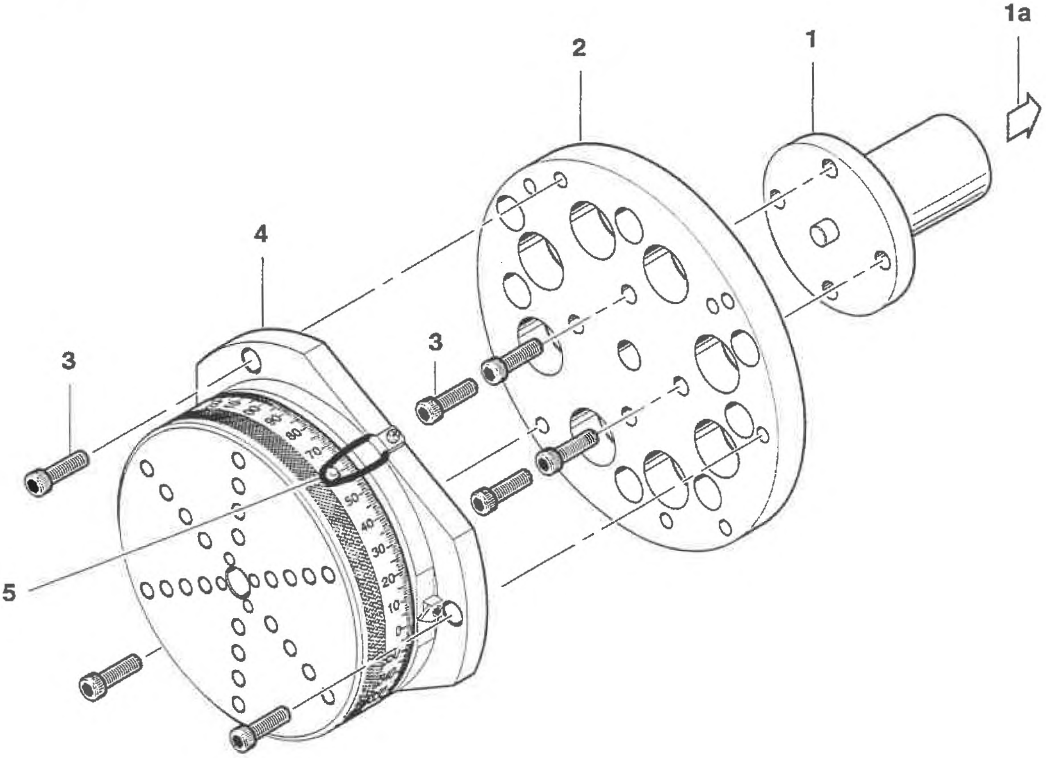
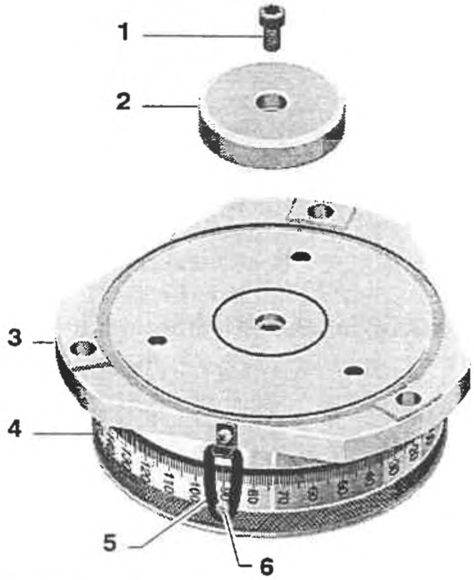


Figure 4-21. Mounting on a machining center

1	Screw, machine
2	Locking ring
3	Precision index table base
4	Precision index table top
5	Locking loop
6	Standoff for locking loop



The locking loops (fastened to the precision index table's base) hold onto standoffs on the precision index table's top to keep the top and base from disengaging completely. Use of these loops is an important safety measure that can reduce the possibility of personal injury or damage to the table.

- Use the locking loops when you are setting up or disassembling the measurement hardware.
- Use the locking ring when you store or ship the precision index table.
- Keep the locking loops engaged on their mating standoffs at all times except:
  - When the precision table installation has been completed and you are ready to make a measurement, or
  - When the locking ring is being used to hold the top and base together.

Figure 4-22. Precision index table

Choosing the moveable optic

Use the HP 10771A Angular reflector as the movable optic whenever possible. This setup can easily accommodate the 2-mm lift required for clearance between the top and base of the precision index table.

A setup with the Angular reflector as the moveable optic can handle lifts greater than 2 mm. However, since moving (translating) the reflector translates the return beam at the Laser Head by twice the amount of the lift, you may not be able to maintain adequate return beam strength throughout your measurement.

If the lift required by your measurement causes so much return beam loss that you lose the measurement signal, you can try using the HP 10770A Angular interferometer as the moveable optic, with the Laser Head set for STRAIGHTness, and the beam pointed directly into the reflector's "corner" so the return beam is along the same path. (See Figure 4-30, below.). Be aware, however, that the interferometer's specification for this use is not as good as that of the reflector, and you will have to perform an additional calibration procedure.

When the Angular interferometer is the moveable optic, the return beam is not translated when the optic is moved. The primary limit to lift distance in this situation is the difference in diameter between the laser beam (6 mm) and the diameter of the interferometer's clear aperture (about 20.83 mm). Environmental conditions and alignment can also affect maximum lift with this configuration.

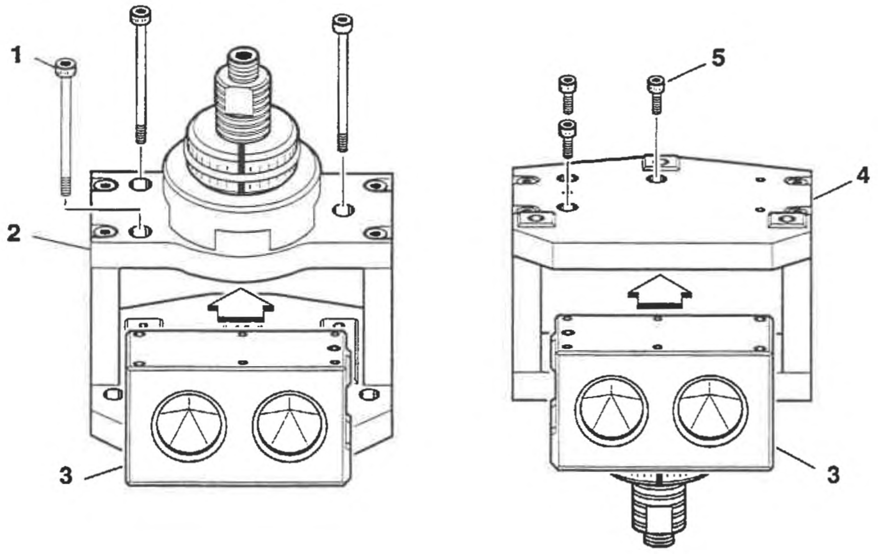
Mounting the moveable optic

Figure 4-23 shows two different arrangements that can be used for mounting the moveable optic in the angular position measurements fixture. Screws for both mounting arrangements are included in the HP 55290A kit.

The top-screw mounting arrangement is recommended for use with newer versions of the retroreflector, whose housings have the required hole configuration.

The bottom-screw mounting arrangement is required for any the measurement optic whose housing does not have the hole configuration required for top-screw mounting.

1	Cap-head machine screw, M3 × 45 mm
2	Fixture top
3	Moveable optic
4	Fixture base
5	Cap-head machine screw, M3 × 10 mm



*

**

Mounting methods—use the appropriate one

*	top-screw mounting—newer optics only
**	bottom-screw mounting—older or newer optics

Figure 4-23. Mounting the moveable optic in the measurement fixture

After mounting the moveable optic in the angular position measurements fixture, mount the fixture on the precision index table.

---

1 Socket-head cap screw, 10-32 × 5/8-inch
2 Measurement fixture
3 Precision index table top

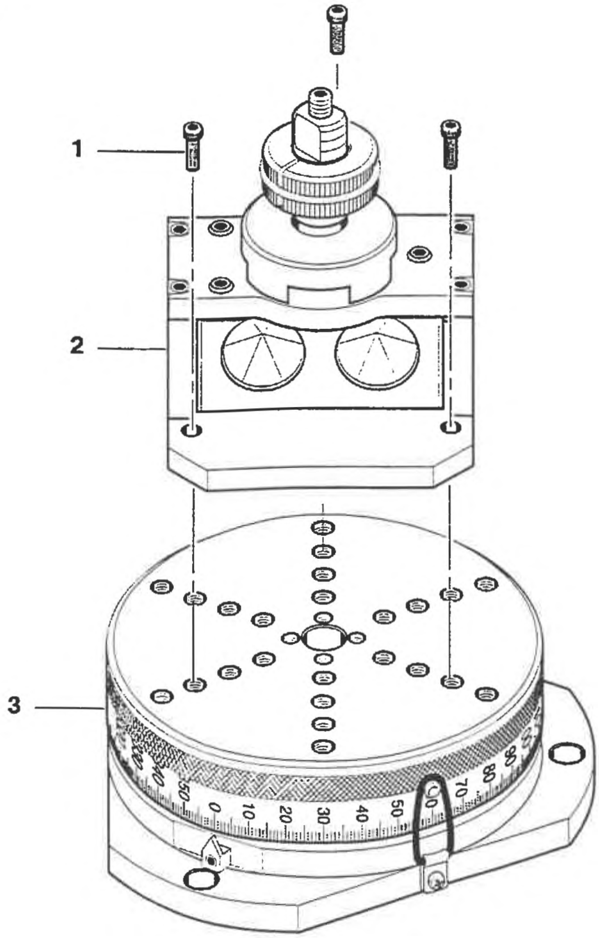


Figure 4-24. Mounting the measurement fixture on the precision index table

Creating the control link

The main goal of the procedures below is to connect the angular position measurement fixture to the machine's spindle or other lifting mechanism while ensuring there is no outside force on the clutch control shaft in any direction. The fixturing aids listed in Figure 4-17 are provided to help you do this.

In long linkages, the HP posts may be too flexible, so custom fixturing may be needed.

Taking care of the measurement fixture's clutch

Refer to Figure 4-25.

The angular position measurements fixture's friction clutch prevents unwanted movement of the precision index table's top when it is disengaged from the table's base.

NOTE

The clutch must never carry any of the weight of the linkage after final assembly and tightening of the linkage.

To prolong clutch life, do not rotate the clutch control shaft with respect to the rest of the fixture when the clutch is engaged. The clutch is normally engaged. To disengage it, rock the control shaft or press it toward the fixture's base.

If the clutch has not been used for more than about two days, it may be difficult to disengage it. Before using the clutch, you should manually disengage it. In this case, you can rock the clutch by manually tilting the clutch control shaft with respect to the rest of the angular measurement fixture.

To keep the clutch from being rocked or disengaged during installation, whether due to the weight of the linkage assembly or due to tightening, hand-tighten the clutch breakaway nut onto the clutch shaft.

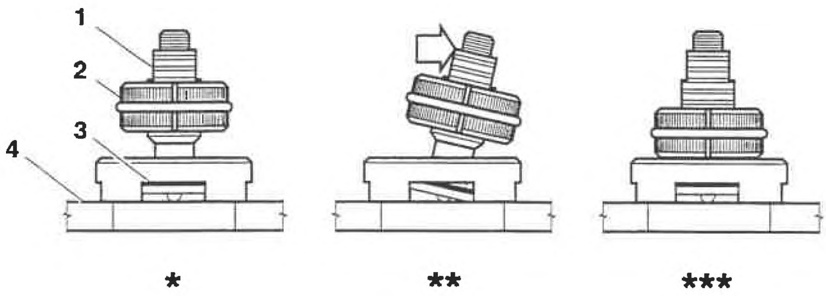
CAUTION

Never use an ordinary nut in place of the clutch breakaway nut. The ordinary nut is not designed to provide the breakaway-under-load protection provided by the HP-provided nut.

After you have assembled and tightened the linkage, unscrew the clutch breakaway nut and position it about 5 mm (1/4-inch) up the shaft, so it does not interfere with operation of the clutch.

Spherical washer sets are particularly useful in right-angle situations, when used with the HP-provided adapter, or on complex linkages where out-of-squareness can be a problem.

1	Clutch control shaft
2	Clutch breakaway nut
3	Clutch washer
4	Top of measurement fixture



*	"Neutral" position
**	Side force rocking (jogging) clutch
***	Breakaway nut tightened to lock clutch in its engaged position **This is done for setups only. Do not lock the clutch during measurements.**

Figure 4-25. Clutch

For parallel spindle and table axes

See Figure 4-26.

1 **Perform all appropriate steps of the setup, mounting, and aligning procedures above.**

NOTE

The clutch breakaway nut is not required for a setup having both the table axis and the spindle axis vertical. However, you may use it in this situation with no problem. If you choose not to use the clutch breakaway nut, modify this procedure accordingly. You should use the clutch breakaway nut in any setup where the table axis is horizontal.

2 **Place the clutch breakaway nut on the clutch control shaft, if it is not already there, but do not tighten it.**

3 **Screw the stub post onto the small threaded portion at the end of the clutch control shaft. Without allowing the shaft to rotate with respect to the rest of the fixture, tighten the stub post onto the shaft.**

4 **If necessary, jog the clutch control shaft to position it in the center of its hole in the angular position measurements fixture.**

5 **Tighten the clutch breakaway nut on the clutch control shaft against the top of the angular position measurements fixture. This locks the clutch in its engaged position, and prevents any load from the linkage hardware from affecting the shaft's position.**

6 **Insert a post in the spindle, with its externally-threaded end extended.**

7 **Position the machine parts as necessary to center the stub post's mating hole at the end of the post in the spindle.**

8 **If necessary, loosen the post in the spindle so it can be brought into contact with the stub post on the clutch control shaft.**

9 **Without allowing the clutch control shaft to turn, screw the end of the post into the end of the stub post on the shaft. Without allowing the clutch control shaft to turn, tighten the post onto the stub post.**

10 **Tighten the post in the spindle.**

11 **Loosen the clutch breakaway nut and run it about 5 mm (1/4-inch) along the clutch control shaft.**

12 **Disengage the locking loops that have been holding the top and bottom of the precision index table together.**

13 **Proceed to the "Mounting the fixed optic" instructions below.**

Ref	Description	Procedure step number →										
1	Spindle					6	7	8	9	10		
2	Post					6	7	8	9	10		
3	Post-stub		3				7	8	9			
4	Clutch breakaway nut	2			5						11	
5	Clutch control shaft	2	3	4	5				9		11	
6	Fixture											
7	Precision index table											
8	Adapter plate											
9	Locking loop(s)											12

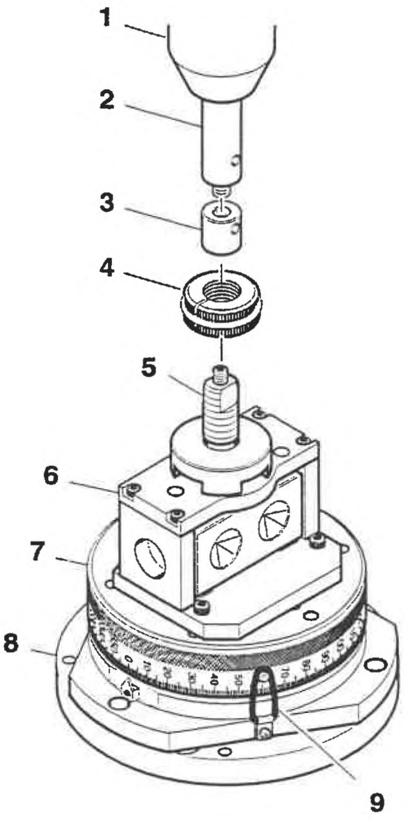


Figure 4-26. Control linkage for parallel axes

For right-angle spindle and table axes

See Figure 4-27 or Figure 4-28.

This case is similar to the parallel-axes case above, except in how the clutch control shaft is connected to the machine's spindle or other part that will control it.

1. **Perform all appropriate steps of the setup, mounting, and aligning procedures above.**

2. **Place the clutch breakaway nut on the clutch control shaft, if it is not already there, but do not tighten it.**

3. **Place the adapter on the clutch control shaft, if it is not already there. Use an open-end wrench to keep the shaft from turning while you use a second wrench to tighten the adapter onto the shaft.**

4. **If necessary, jog the clutch control shaft to position it in the center of its hole in the angular position measurements fixture.**

5. **Insert a post in the spindle, with its externally-threaded end extended.**

6. **Add a stub post to the post in the spindle. Using a wrench or similar tool through the hole in each post, tighten the posts together.**

7. **If necessary, loosen the post assembly in the spindle so its end can touch the adapter on the clutch control shaft.**

8. **Rotate the adapter (and clutch control shaft) so the adapter's mating face is parallel with the end of the post assembly in the spindle and the clearance hole lines up correctly. If more than a few degrees of turning is necessary, jog the control shaft as you turn it, to reduce clutch engagement. Turning the shaft with the clutch engaged increases wear on the clutch, shortening its useful life.**

9 **Position the machine as necessary to center the adapter's clearance hole on the end of the post assembly in the spindle.**

10 **Back the post assembly away from the adapter, so it does not exert any force on the clutch control shaft.**

11 **Tighten the clutch breakaway nut on the clutch control shaft against the top of the angular position measurements fixture.** This locks the clutch in its engaged position, and prevents any load from the linkage hardware from affecting the shaft's position.

12 **Fasten the adapter to the stub post at the end of the post assembly, using the spherical washers and bolt provided.**

13 **Tighten the post assembly in the spindle.**

14 **Loosen the clutch breakaway nut and run it about 5 mm (1/4-inch) along the clutch control shaft.**

15 **Disengage the locking loops that have been holding the top and bottom of the precision index table together.**

16 **Proceed to the "Mounting the fixed optic" instructions below.**

Ref	Description	Procedure step number →														
1	Post				5		7	8	9			12	13	14		
2	Post-stub					6	7	8	9				13			
3	Spherical washers												13			
4	Adapter		3				7	8	9				13			
5	Socket-head cap screw, M10 × 40 mm												13			
6	Clutch breakaway nut	2									11				15	
7	Clutch control shaft	2	3	4			7			10	11				15	
8	Fixture															
9	Precision index table															
10	Adapter plate															
11	Locking loop(s)															16

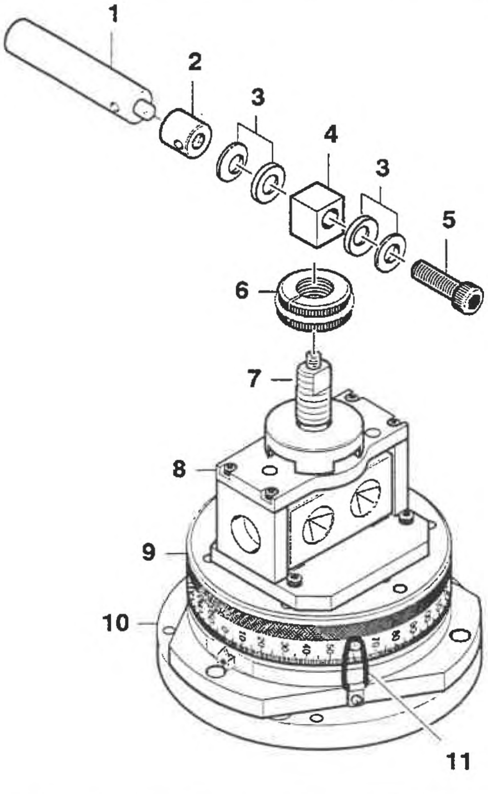


Figure 4-27. Control linkage for horizontal spindle axis and vertical table axis

Ref	Description	Procedure steps ➜															
1	Post					6		8	9	10	11	12		14	15		
2	Post-stub						7	8	9	10	11	12		14			
3	Spherical washers													14			
4	Adapter			4				8	9	10	11	12		14			
5	Socket-head cap screw, M10 × 40 mm													14			
6	Clutch breakaway nut		3										13			16	
7	Clutch control shaft		3		5			8					13				
8	Fixture, with optic installed	2															
9	Precision index table	2															
10	Adapter plate																
11	Locking loop(s)																17

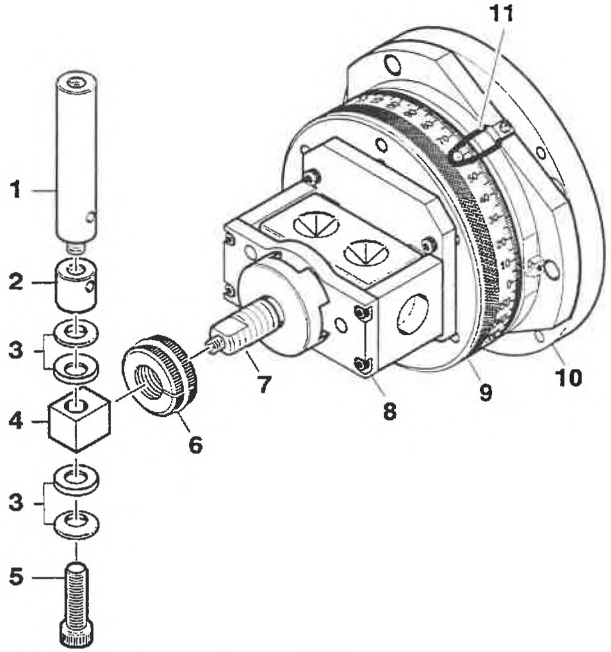


Figure 4-28. Control linkage for vertical spindle axis and horizontal table axis

Mounting the fixed optic

1 **Create the supporting arrangement for the fixed optic. For the best measurement accuracy, this arrangement must minimize any possible movement of the fixed optic. A multi-post arrangement (see Figure 4-29) will usually provide a much stiffer support than a single post.**

2 **Attach the fixed optic to its support.**

3 **Place the fixed optic in its position in the laser path, as close to the moveable optic as possible.**

CAUTION Be sure to position the fixed optic so it will not be hit by any moving part. Be sure to provide enough clearance between the fixed optic and the angular position measurement fixture's base.

NOTE This procedure was presented here for the majority of expected setups, where the angular reflector is the moveable optic and the angular interferometer is the fixed optic. If the angular reflector is the fixed optic, perform the optics alignment procedure above after you install it.

1. Socket-head cap screw, M10 × 10 mm
2. Optic
3. Height adjuster
4. Base
5. Post
6. Gusset

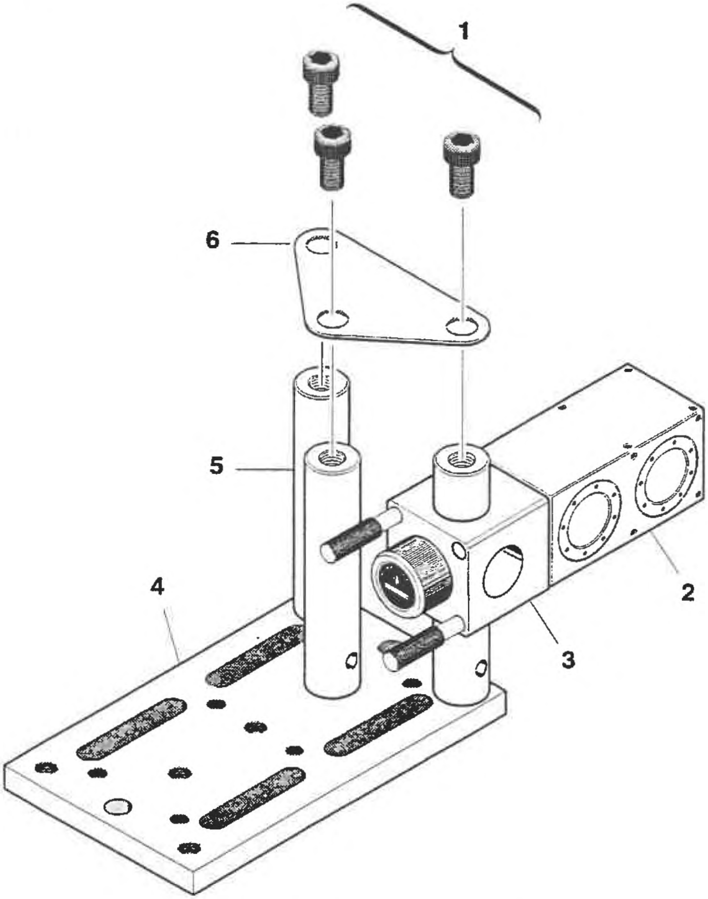


Figure 4-29. Setup for fixed optic

Aligning the laser beam

NOTE

This procedure is presented here for the majority of expected setups, where the angular reflector is the moveable optic and the angular interferometer is the fixed optic. If the angular reflector is the fixed optic, perform this procedure after you install it.

NOTE

This procedure assumes setups as shown in Figure 4-30.

*	Retroreflector as moving optic
**	Interferometer as moving optic

1	Laser head
2	Angular interferometer
2a	Laser beam(s) at interferometer
3	Angular reflector
3a	Laser beam(s) at reflector

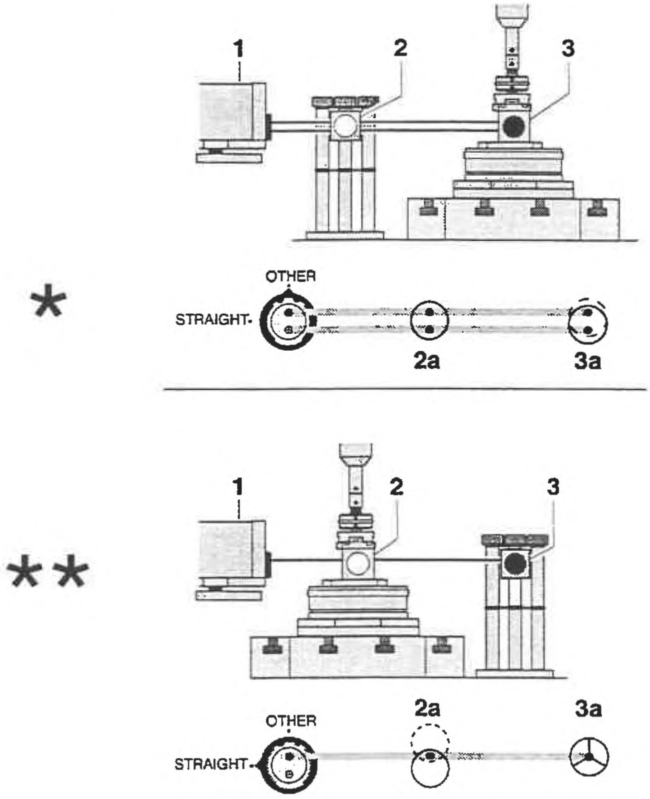

1
2
3
*
OTHER
STRAIGHT
2a
3a
1
2
3
**
2a
3a
OTHER
STRAIGHT

Figure 4-30. Typical setups for vertical and horizontal table axes (Part 1 of 2)

1 Laser head

2 Angular interferometer

3 Angular reflector

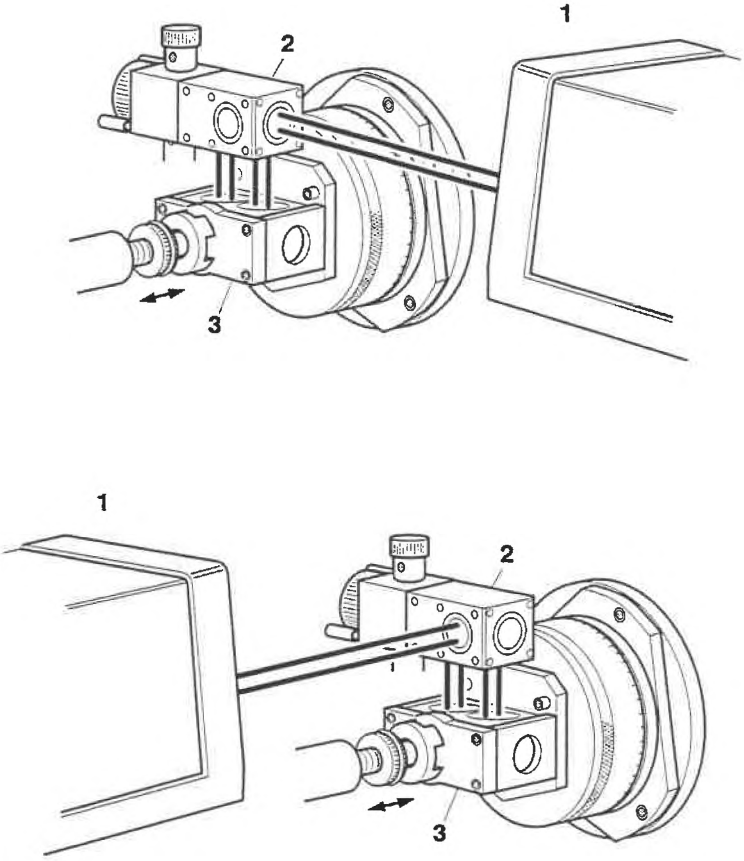


Figure 4-30. Typical setups for vertical and horizontal table axes (Part 2 of 2)

To align the laser beam, follow these steps:

1. **Orient the angular reflector as you want it to be for your measurement.**
2. **Mount the interferometer in the beam path, so the beam passes through it to the reflector. No other alignment is needed at this time.**
3. **Set the laser head's upper port to the small aperture by turning the upper aperture control (see Figure 2–13).**
4. **Rotate the target into position on laser head's lower port by turning the lower aperture control.**
5. **Set the laser head's turret ring to OTHER.**
6. **Position and align the laser head so its beam enters one of the reflector's ports and is perpendicular to the port's surface.**
7. **Place a gage block over the port so it can reflect the laser beam back to the laser head.**
8. **Rotate the laser head so the beam from the gage block reflects back to its upper (output) port.**
9. **Remove the gage block from the angular reflector.**
10. **Translate the laser head so the return beam centers on the target at its lower (return) port**
11. **Secure the reflector to the target machine, maintaining the return beam's position in the center of the laser head's target.**
12. **You can adjust the interferometer the same way you adjusted the angular reflector.**

You are now ready to align the laser beam to the machine's travel path.

If your measurement distance is less than 350 mm (14 inches), go directly to “Aligning the laser beam to the machine’s travel path for short-range measurements,” in Chapter 2.

If your measurement distance is greater than 350 mm (14 inches), continue with the next section, “Aligning the laser beam to the machine’s travel path for long-range measurements,” in Chapter 2.

13 **After you have finished performing the appropriate alignment procedure described above, continue at “Checking your installation,” below.**

Checking your installation

This procedure assumes that you have

1. created an appropriate program to control the machine for the measurement
2. installed the precision index table and measurement optics for an angular position measurement as instructed earlier in this chapter.

Checking your installation consists of:

- a) setting the machine’s relative zero point for your setup, and
- b) performing final alignment of the optics and laser beam,
- c) checking integrity of your measurement setup

To set the machine’s relative zero point for your measurement

This procedure assumes that physical setup has been completed, and that you have not yet used the machine to disengage the clutch. That is, the measurement setup is in its “neutral” position.

If you have already used the machine to disengage the clutch, return the clutch to its neutral position. One way to do this is to loosen the connection between the clutch control shaft and the part of the machine that is providing the lifting action for the measurement fixture and precision index table top. Then tighten the connection again.

1 **Starting from the initial conditions described above, move the clutch controlling mechanism 2 mm in the direction that separates the top and base of the precision index table.**

2 **Set the machine's relative zero point. This is the zero value that will be used by the program that you entered earlier during your installation**

To perform final optics alignment and integrity check

CAUTION If you change the machine's relative zero point for this measurement, or if you change any part of the lifting connection between machine and the measuring hardware, be sure to reset the relative zero point as described above.

1 **Carefully check the clearances of all parts as you use the machine's manual controls to slowly move its parts as they will be moved during the actual measurement. STOP IMMEDIATELY if you detect any indication of a possible problem, then fix as necessary.**

2 **Use the machine's manual controls to move the moveable optic through the entire measurement range while you view the result of the return spot on the target at the laser head's return port. The beam should remain on the port, and the SIGNAL indicator must remain lighted. When the SIGNAL indicator is not lighted, the Laser Head is not receiving a strong enough signal to make a measurement.**

3 **Manually step the machine through the control program you entered earlier, until you are satisfied that the machine will perform as you want it to.**

Controlling the machine during the measurement

Because of the variety of controllers, it is not possible to present specific instructions for any particular one here. Apply the information presented here to your measurement situation.

As described earlier in this manual chapter, making a measurement consists of these activities:

1. Disengaging the precision index table top from its base.

   For the hardware described in this manual chapter, disengagement requires 2 mm (0.08 inch) of movement from the “neutral” closed position. (See Figure 4-31.)

2. Rotating the precision index table’s base with respect to its top.

   Although the optic mounted on the table is considered the “moveable” optic, its movement is minimal, compared to some other applications.

3. Engaging the precision index table top and base, and applying a clamping force to disengage the clutch and ensure good seating of the two parts of the table.

   For the hardware described in this chapter, engagement requires moving the clutch control shaft 1.0 mm (0.04 inch) past the “neutral” closed position. (See Figure 4-31.)

4. Commanding the HP 5529A calibrator to record the measurement data.

Manually stepping through the machine control program

Step through your machine control program manually before you run it automatically. While you are doing this, be sure to check the physical integrity of your setup, to be sure the program has not introduced any problems you did not encounter during your earlier manual check. Fix any problem that you detect.

Running the machine control program

After your program has passed your manual operation check, run it automatically. While you are doing this, you can also check to be sure you have set the HP 5529A calibrator to record data at the appropriate times. Be sure your program has enough dwell time for the HP 5529A to record an appropriate value.

Making the measurement

In this procedure, you make automatic measurements as you rotate the precision index table's base. If you are using sensors, make sure they are properly placed and the software is set up correctly. (Refer to the *HP 5529A Getting Started Guide* for complete instructions on using the software and the sensors.)

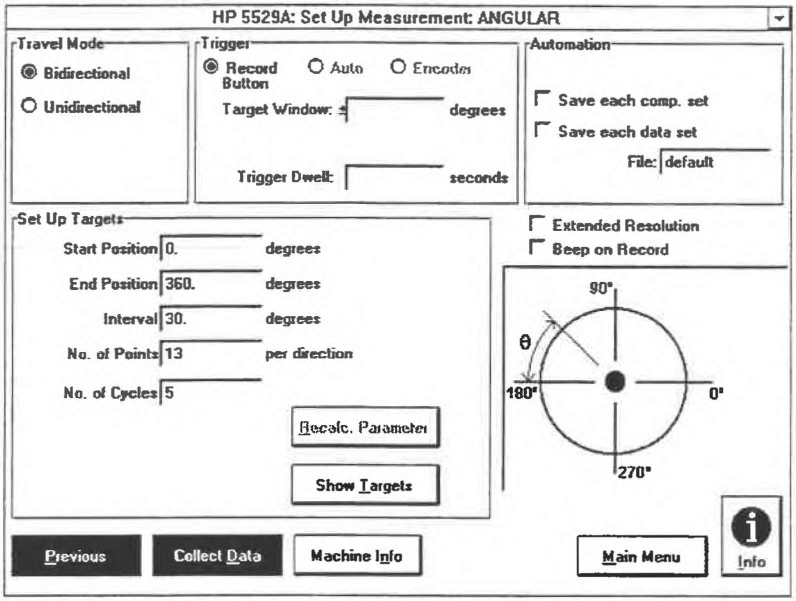
This section explains how to make measurements using the Record button in the software and the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

To make the measurement, follow these steps:

1 **Perform one measurement cycle, to place the measurement optic at its start position.**

2 **On the Set Up Laser: ANGULAR window, select Set Up Meas.**

The Set Up Measurement: ANGULAR screen is displayed (Figure 4-31).



HP 5529A: Set Up Measurement: ANGULAR

Travel Mode
● Bidirectional
○ Unidirectional

Trigger
● Record Button ○ Auto ○ Encoder
Target Window: ± degrees
Trigger Dwell: seconds

Automation
☐ Save each comp. set
☐ Save each data set
File: default

Set Up Targets
Start Position: 0. degrees
End Position: 360. degrees
Interval: 30. degrees
No. of Points: 13 per direction
No. of Cycles: 5

☐ Extended Resolution
☐ Beep on Record

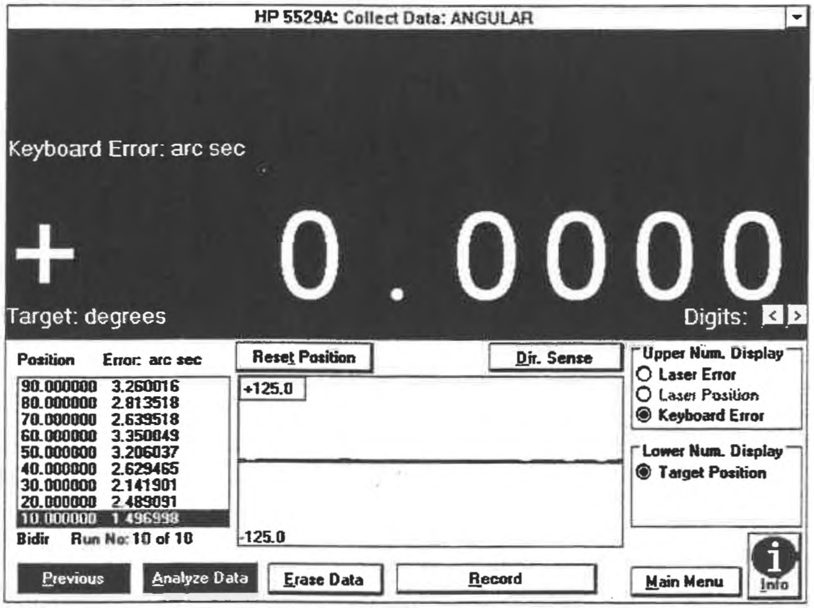
Figure 4-31. Set Up Measurement: Angular screen

3 **Complete the fields on the Set Up Measurement: ANGULAR screen.**

If necessary, use the online help.

4 **Select Collect Data.**

The Collect Data: ANGULAR screen is displayed (Figure 4-32).


HP 5529A: Collect Data: ANGULAR
Keyboard Error: arc sec
+ 0.0000
Target: degrees
Digits: < >
Reset Position
Dir. Sense
+125.0
-125.0
Previous
Analyze Data
Erase Data
Record
Main Menu
Info

Position	Error: arc sec
90.000000	3.260016
80.000000	2.813518
70.000000	2.639518
60.000000	3.350049
50.000000	3.206037
40.000000	2.629465
30.000000	2.141901
20.000000	2.489091
10.000000	1.496998

Bidir Run No: 10 of 10

Upper Num. Display
○ Laser Error
○ Laser Position
● Keyboard Error

Lower Num. Display
● Target Position

Figure 4-32. Collect Data: ANGULAR screen

5 On the Collect Data: ANGULAR screen, select Reset Position.

This tells the HP 5529A calibrator that the current position of the moveable optic (the machine's relative zero point) is the "zero" point from which all angular positions will be measured.

If necessary, use the online help to complete the rest of the fields on this screen.

6 Move the precision index table's base to the first measurement point.

7 Select Record.

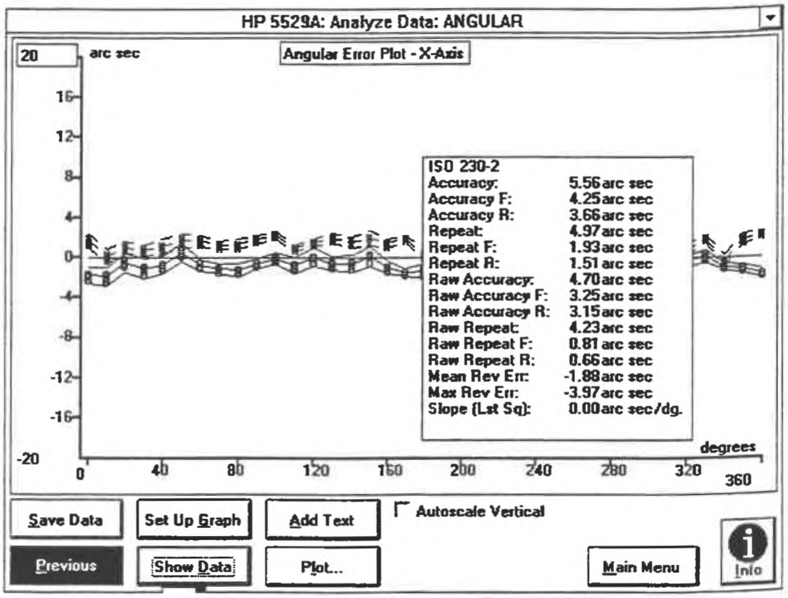
If you are using the optional remote control unit, press the Record button.

8 **Continue moving precision index table's base to each angular position and recording data until the machine has reached the last measurement position.**

NOTE

If at any point the Reset Laser message flashes, the laser beam path has been broken. Return the precision index table's base to the last angular position measured, then select Reset Position to reset the system.

After the last measurement is recorded, the Analyze Data: Angular screen is displayed (Figure 4-33).


HP 5529A: Analyze Data: ANGULAR
20
arc sec
Angular Error Plot - X-Axis
16
12
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
160
200
240
280
320
360
degrees
Save Data
Set Up Graph
Add Text
Autoscale Vertical
Previous
Show Data
Plot...
Main Menu
Info

ISO 230-2

Accuracy:	5.56 arc sec
Accuracy F:	4.25 arc sec
Accuracy R:	3.66 arc sec
Repeat:	4.97 arc sec
Repeat F:	1.93 arc sec
Repeat R:	1.51 arc sec
Raw Accuracy:	4.70 arc sec
Raw Accuracy F:	3.25 arc sec
Raw Accuracy R:	3.15 arc sec
Raw Repeat:	4.23 arc sec
Raw Repeat F:	0.81 arc sec
Raw Repeat R:	0.66 arc sec
Mean Rev Err:	-1.88 arc sec
Max Rev Err:	-3.97 arc sec
Slope (Lst Sq):	0.00 arc sec/dg.

Figure 4-33. Analyze Data: ANGULAR screen

9 **On the Analyze Data: ANGULAR screen, select Save Data to create or update a data file with the measurement data.**

Refer to the HP *5529A Getting Started Guide* and online help for more information about using this screen. Otherwise, you are finished making the measurement.

Storing the hardware

Return the angular position measurement kit components to the kit case when you have finished using them.

NOTE

Before you store the precision index table:

1. Install the locking ring and bolt to hold the top and bottom together. Tighten the bolt securely.
2. After performing step 1, disengage the locking loops. This helps extend their useful life.

Maintenance

Precision index table

The precision index table's top and base have 360 matching teeth comprising a hirth coupling. For best performance of the table, these teeth should be as clean as possible. You should visually inspect the teeth each time you use the table. The procedure below is recommended for cleaning hirth coupling teeth.

WARNING

BE SURE TO WEAR APPROPRIATE PROTECTIVE SHIELDING AND CLOTHING WHEN WORKING WITH COMPRESSED AIR AND ACETONE.

1 **With the precision index table's top and bottom separated, use compressed air to blow loose material from the hirth coupling teeth.**

2 **If necessary, use an acid brush to remove material from the teeth.**

3 **If necessary, use acetone and the acid brush to remove material from the teeth.**

4 **Rejoin the precision index table's top and base, and use the locking loops to hold them together. If you will be storing the table, be sure to read the storage instructions above.**

Clutch

The angular position measurements fixture's clutch uses a non-metallic washer glued to the end of the clutch control shaft. Occasionally, due to wear or contamination, you may have to clean or replace this washer. The procedures to do this are given below.

Disassembly

1 **Remove the fixture from the precision index table, if necessary.**

2 **Remove any optic mounted in the fixture, if necessary.**

NOTE The clutch spring exerts slight pressure between the retainer ring and the fixture's top plate.

3 **Remove the four M4 hex-drive cap-head screws that fasten the clutch retainer ring to the top plate.**

4 **Remove the clutch shaft from the retainer ring.**

5 **Perform the cleaning or replacement procedures below.**

Cleaning the clutch washer

1 **If necessary, perform the disassembly procedure above.**

2 **Using suitable solvent such as soap, wash, then dry the clutch washer and its mating surface on the underside of the clutch retainer ring. Be careful to thoroughly dry these parts and not to contaminate their surfaces with fingerprints or anything else that may act as a lubricant.**

3 **Replace the clutch control shaft in the retainer ring and re-attach the retainer ring to the fixture's top plate. Only slight pressure is required to overcome the pressure of the clutch spring that tends to push the ring and plate apart.**

Replacing the clutch washer

1. **If necessary, perform the disassembly procedure above.**
2. **Carefully separate the washer from the bottom of the clutch control shaft. The washer is held in place by an adhesive on one side.**
3. **Remove the washer from the shaft. Since you should not be reusing this washer, you can cut it to make removal easier.**
4. **Note that the replacement washer has a protective paper layer on one side. This paper is intended to help keep the washer's adhesive sticky until the end of the installation procedure. The paper has radial cuts to allow it to expand as needed during the installation. Do not remove the protective paper until instructed to do so.**
5. **Carefully slide the clutch washer, paper-covered adhesive-side first, onto and along the clutch control shaft, until it reaches the non-threaded portion just above the end of the shaft.**
6. **Remove the protective paper, being careful to minimize the amount of handling, to keep from contaminating the adhesive with your fingerprints. Then press the washer onto the base of the shaft.**
7. **If you think it necessary, perform the cleaning procedure above, to remove fingerprints from the newly-installed washer.**
8. **Replace the clutch control shaft in the retainer ring and re-attach the retainer ring to the fixture's top plate. Only slight pressure is required to overcome the pressure of the clutch spring that tends to push the ring and plate apart.**

Step	Art	Procedure
1	—	Remove optic, if necessary
2	1	Remove four M4 cap screws holding retainer ring to fixture top plate
3	1	Remove clutch control shaft from retainer ring
4	2	Remove clutch washer from base of clutch shaft
5	3	Cut clutch washer and remove from shaft
6	4	Slide new clutch washer onto shaft—paper-covered adhesive side first
7	—	Remove protective paper from adhesive
8	—	Press washer onto base
9	1	Replace shaft in retainer ring
10	1	Fasten retainer ring to fixture top plate

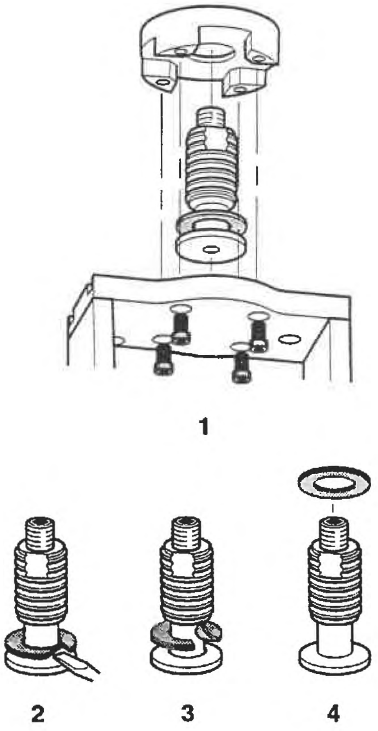


Figure 4-34. Replacing the clutch washer

Clutch Breakaway Nut

If the clutch breakaway-nut breaks, order a replacement clutch breakaway-nut (HP part number 55290-67002).

CAUTION

To prevent damage to your machine or the measurement apparatus, do not use any other type of device in place of the clutch breakaway-nut.

The clutch breakaway-nut o-ring is provided as a reminder to loosen the clutch breakaway-nut before you make a measurement. It does not contribute to the strength of the breakaway nut itself. If the o-ring breaks or is lost, you may continue to use the breakaway nut. The o-ring is not separately replaceable; it is supplied as part of the clutch breakaway-nut (HP part number 55290-67002).

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A

Operating specifications

Operating specifications

This appendix lists the operating specifications for the HP 5529A dynamic calibrator.

Table A–1. General specifications

Characteristic	Specification
Axis velocity, using Linear optics (HP 10766A interferometer).	700 mm (27.6 in) per second, using HP 5519A Laser Head 1000 mm (39.4 in) per second, using HP 5519B Laser Head
Power requirements—electronics	2.6 A at 5 Vdc; 15 mA at ±12 Vdc (from the PC)
Data rate	Depends on computer type. Typical rates are listed below. Computer Typical rate 386 ≥ 1 kHz (100 Hz with extended resolution) 486/33 6.7 kHz 486/66 12 kHz Pentium 90 33 kHz[1]
A quad B differential input threshold	±0.5 V minimum; ±7.0 V maximum
A quad B differential input impedance	100 Ohms or high-impedance
A quad B input rate	> 100 ns edge-to-edge, or < 10 MHz information rate Example: If A quad B is moving at maximum speed, A and B both must be < 2.5 MHz.

[1] Start Timer: invoked from computer (not from remote).

5. Straightness measurements

5. Straightness measurements

5

Straightness measurements

Straightness measurements

This chapter explains how to make straightness measurements that allow you to determine if a machine's moveable part is moving along a straight path. Before performing the procedures described in this chapter, you must fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide.* For operating specifications for straightness measurement optics, see Appendix A.

Straightness and squareness measurements are usually done together, since a squareness measurement is actually two straightness measurements perpendicular to each other.

The procedures in this chapter explain how to make straightness measurements only. Follow them in the event that you are not going to combine straightness and squareness measurements.

If you plan to make straightness *and* squareness measurements, you can perform the straightness measurements as part of a squareness measurement. Depending on whether your measurements are in a horizontal or vertical plane, go to either Chapter 6, "Squareness measurements in a horizontal plane," or Chapter 7, "Squareness measurements in a vertical plane."

Straightness accessory kit, p/n 10776A:

1 Reflector mount, p/n 10776-67002

2 Retroreflector, p/n 10776-67001

3 Interferometer base plate, p/n 10776-20011

4 Reflector base and posts, p/n 10776-67008

* * *

Long-range optics kit, p/n 10775A:

5 Long-range reflector

6 Long-range interferometer

* * *

Short-range optics kit, p/n 10774A:

7 Short-range reflector

8 Short-range interferometer

* * *

9 Interferometer target, p/n 10774-67001

* * *

10 Height adjuster and post, p/n 10785A

* * *

Turning mirror kit, p/n 10772A:

11 Turning mirror, p/n 10772-67002

12 Turning mirror base, p/n 10772-67001

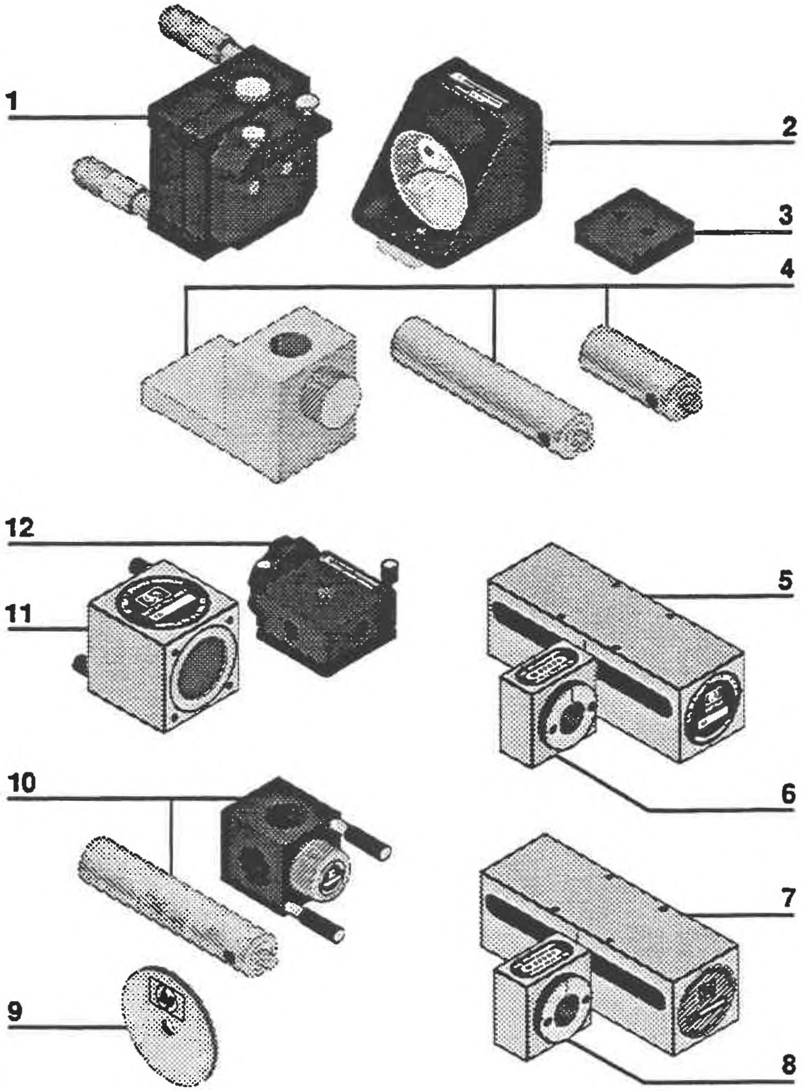


Figure 5–1. Required hardware for straightness measurements

Setting up for the measurement

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter to make a straightness measurement. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head, remote control unit, and sensors (if used) to the connectors on the 10886A and 10887A boards installed in the computer.**

The connectors are either on the rear or the side of the computer.

3 **Plug in and turn on all equipment.**

4 **Start the metrology software.**

The Metrology Main Menu is displayed.

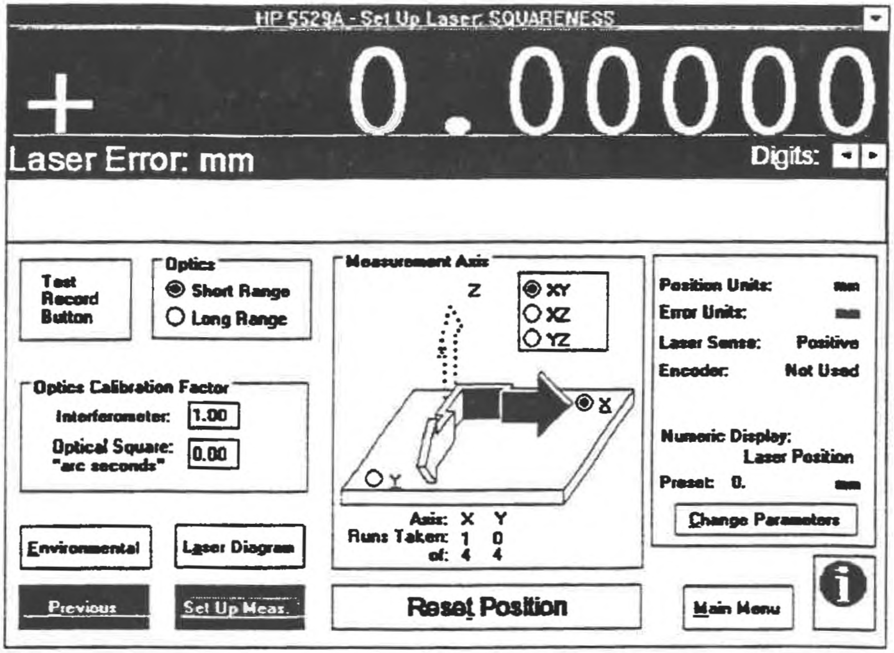
5 **On the Metrology Main Menu, select Straightness.**

The Set Up Laser: Straightness screen (Figure 5–2) is displayed.

Alternately, you can open an existing straightness measurement setup file by selecting Recall Data on the Main Menu.

6 **Complete the fields on the Set Up Laser: Straightness screen.**

If necessary, use the online help.



HP 5529A - Set Up Laser: SQUARENESS

+ 0.00000

Laser Error: mm

Optics: ● Short Range ○ Long Range

Optics Calibration Factor
Interferometer: 1.00
Optical Square: "arc seconds" 0.00

Measurement Axis: ● XY ○ XZ ○ YZ

● X ○ Y

Axis:	X	Y
Runs Taken:	1	0
of:	4	4

Position Units: mm
Error Units: mm
Laser Sense: Positive
Encoder: Not Used

Numeric Display: Laser Position
Preset: 0. mm

Digits:
Test Record Button
Z
Environmental
Laser Diagram
Previous
Set Up Meas.
Reset Position
Change Parameters
Main Menu

Figure 5–2. Set Up Laser: Straightness screen

Positioning the laser head and target machine

Before you begin to assemble and mount optics, you must position the laser head and move the target machine to its initial position. Follow these steps:

1 **Position the laser head along the axis most suitable for the measurement that you want to make (figure 5–3, 5–4, or 5–5).**

A Measurement in a horizontal plane along the X-axis or Y-axis

B Measurement in a vertical plane along the X-axis or Y-axis

……

1 Reflector oriented horizontally

2 Interferometer mounted in a spindle

3 Laser head

4 Reflector oriented vertically

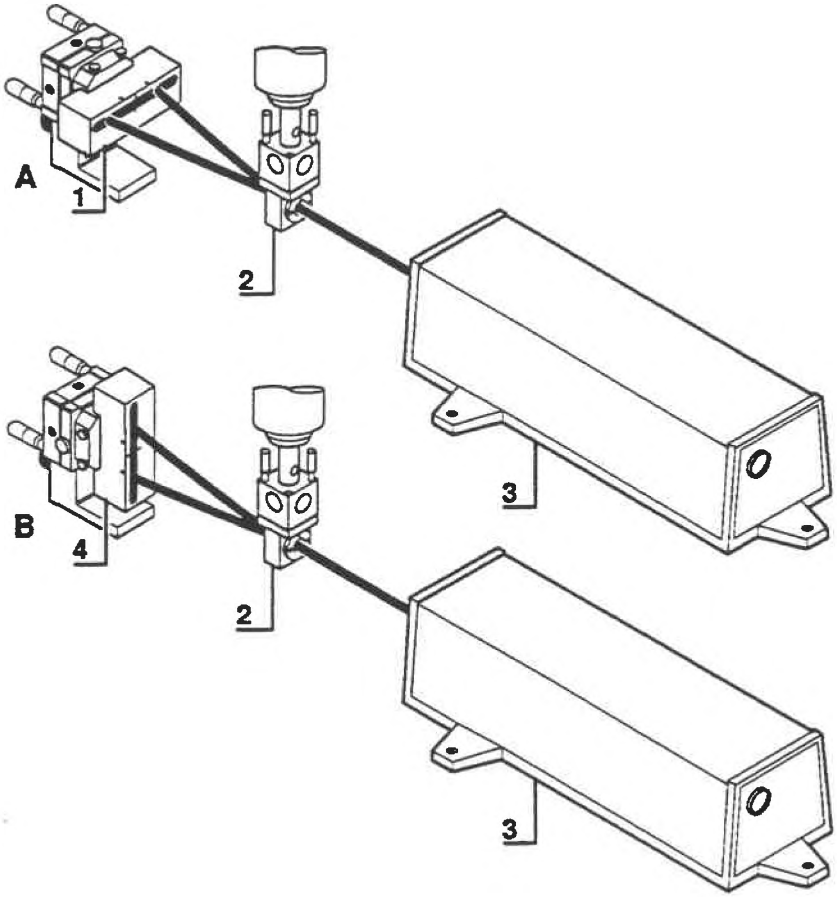


Figure 5–3. Positioning of optics for X-axis and Y-axis measurements

A Measurement perpendicular to the laser head along the Z-axis

B Measurement parallel to the laser head along the Z-axis

••••••••••••••••••••••••

1 Interferometer assembly mounted in a spindle

2 Reflector oriented perpendicular to the laser head

3 Laser beam

4 Laser head

5 Reflector oriented parallel to laser head

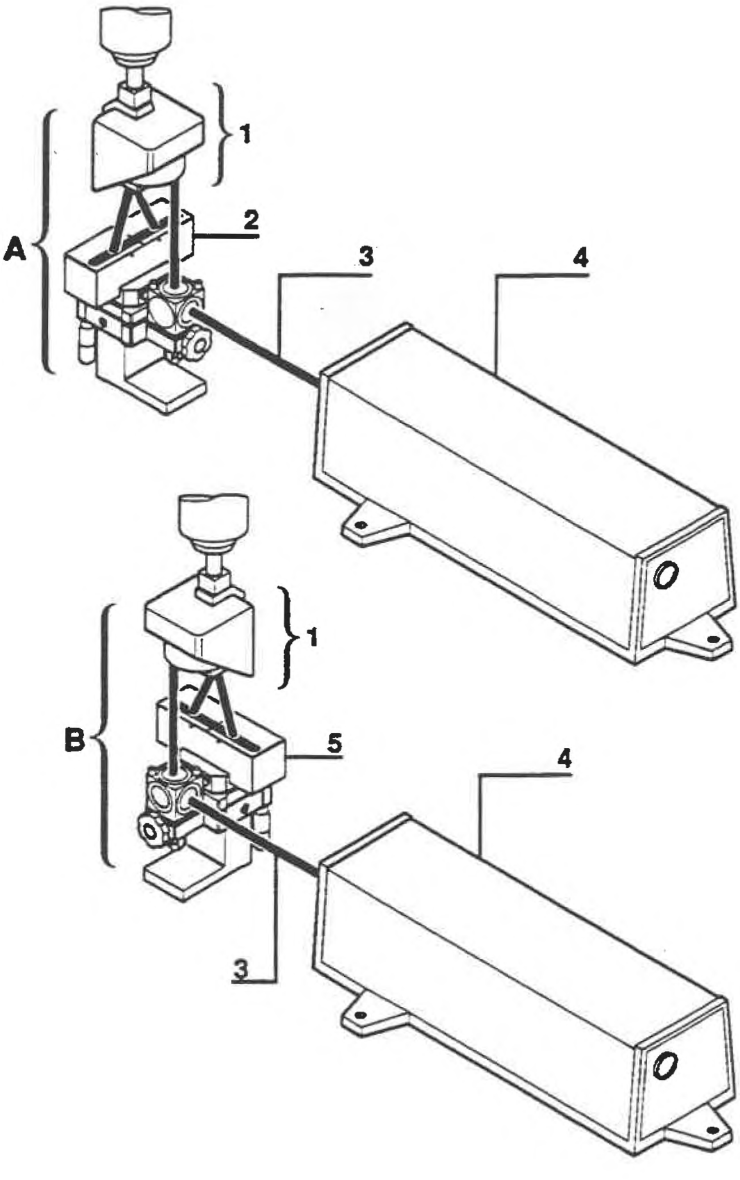


Figure 5–4. Positioning of optics for a vertical Z-axis measurement

A Measurement in a horizontal plane along the Z-axis

B Measurement in a vertical plane along the Z-axis

****

1 Interferometer assembly oriented horizontally in a spindle

2 Interferometer assembly oriented vertically in a spindle

3 Reflector oriented vertically

4 Laser head

5 Reflector oriented horizontally

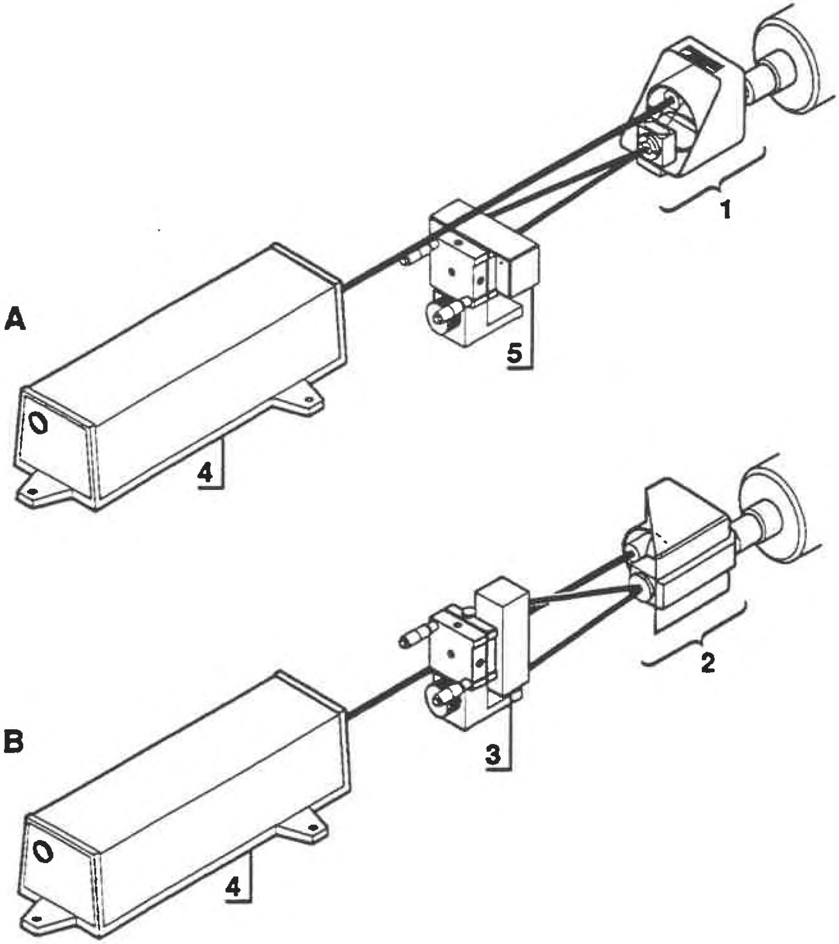


Figure 5–5. Positioning of optics for a horizontal Z-axis measurement

2 **If the machine's table moves, move it as close as possible to the laser head.**

3 **If the machine's spindle moves, move it as far as possible from the laser head.**

Steps 2 and 3 ensure that any movement of the machine's moveable part will move the optics apart, not toward each other. This decreases the possibility of damaging them.

4 **Adjust the laser head to the approximate height at which you will mount the optics.**

5 **Determine how to position the optics. See figure 5–3, 5–4, and 5–5 for sample setups, and use the following guidelines:**

- Mount the interferometer or the combined retroreflector/interferometer where the tool mounts.
- Mount the reflector where the workpiece mounts.

Note This chapter uses a machine with a spindle as an example for making straightness measurements. Although your machine may be different, the general procedures described here still apply.

Your measurement will determine how straight a machine will cut or measure a workpiece. The measurement corresponds to a straightedge and dial indicator measurement.

You are now ready to assemble, mount, and align the optics.

To make a straightness measurement along the vertical Z-axis, go directly to "Making vertical axis straightness measurements" later in this chapter.

To make a straightness measurement along the X-axis or Y-axis, continue with the next section, "Mounting and aligning optics for X-axis or Y-axis measurements."

Mounting and aligning optics for X-axis or Y-axis measurements

This section explains how to assemble, mount, and align optics for straightness measurements along the X-axis or Y-axis.

Mounting the optics

To assemble the optics and mount them on the machine, follow these steps:

1. **Connect the interferometer to its base using the attachment screws provided (Figure 5–6).**
2. **Connect the post to the interferometer using *either* of the following methods (one method uses the height adjuster, the other does not):**
   - Remove the large knurled knob from the height adjuster, connect the height adjuster to the interferometer's base plate using the attachment screws, and screw the post into the height adjuster (Figure 5–6). Use this method if you plan to make other types of measurements later; it will take less time to change the optics.
   - Screw the post directly into the interferometer's base plate (Figure 5–7).
3. **Secure the post in the machine spindle.**

1 Spindle
2 Post
3 Height adjuster
4 Attachment screws
5 Interferometer's base plate
6 Interferometer

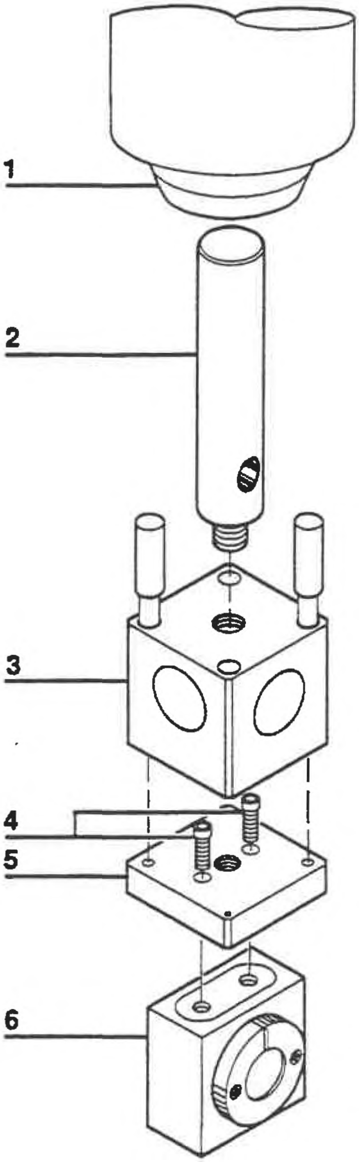


Figure 5–6. Assembling and mounting the interferometer with the height adjuster

1 Spindle
2 Post
3 Attachment screws
4 Interferometer's base plate
5 Interferometer

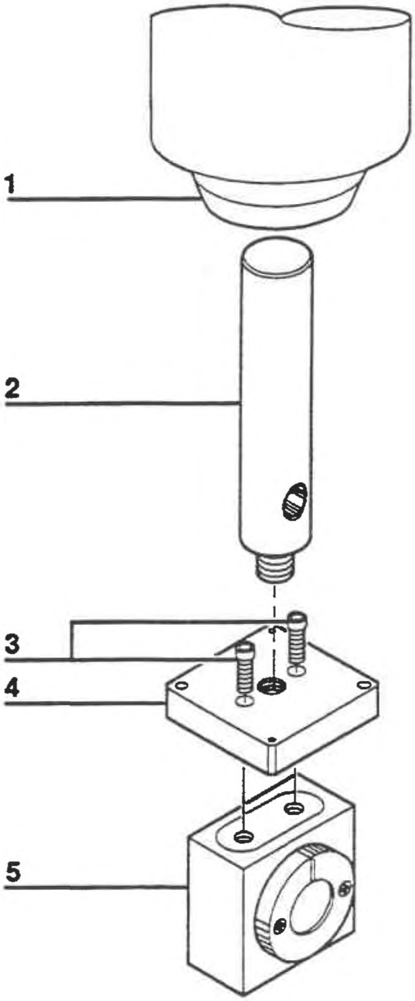


Figure 5–7. Assembling and mounting the interferometer without the height adjuster

4 **Assemble the reflector and its mounting hardware as shown in Figure 5–8.**

Position the reflector so the slot is closest to the top edge.

1 Reflector mount
2 Reflector rotation screw
3 Reflector attachment screws
4 Reflector
5 Reflector post
6 Reflector base

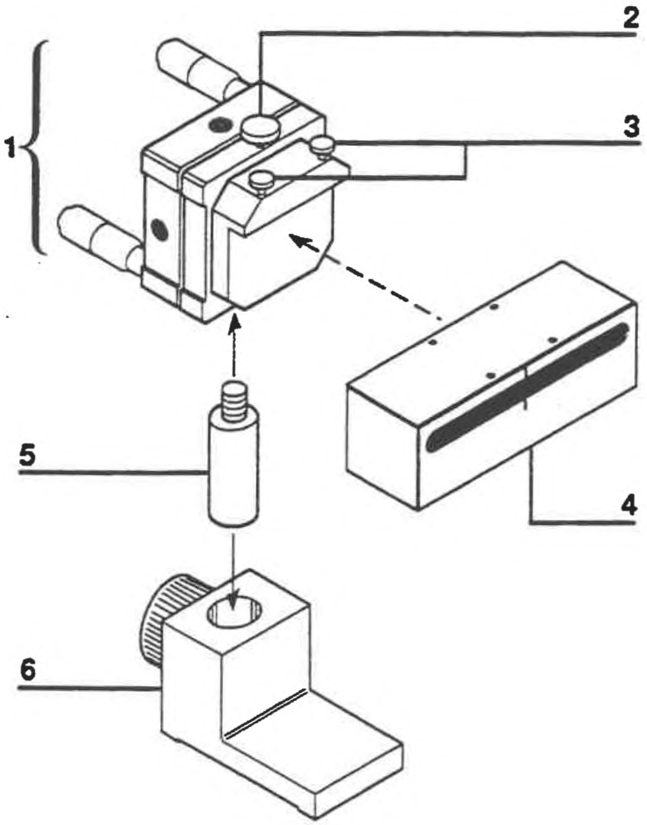


Figure 5–8. Assembling the reflector assembly

Note If you will be making a linear or angular measurement after the straightness measurement, position the reflector as low as possible on its base without covering up the hole in the post. Also, position the laser head so its beam strikes the center of the slot on the reflector.

5 **If you plan to make a straightness measurement in a vertical plane, loosen the rotation screw (Figure 5–8), rotate the reflector 90 degrees, and tighten the screw.**

6 **Place the reflector assembly on the target machine as shown in Figure 5–3. Make sure the reflector assembly is no closer than**

- 100 mm (4 inches) to the interferometer for *short-range* measurements
- 900 mm (36 inches) for *long-range* measurements.

This ensures that the two beams from the interferometer strikes the reflector properly. Each of the two beams must strike one of the mirrors in the reflector (figure 5–3, 5–4, or 5–5).

Note Although the mounting assembly provided with the reflector provides considerable mounting flexibility, there may be some situations when you need added flexibility. Figure 2–12 shows how you can use additional hardware to increase flexibility.

Aligning the optics

Make sure the large aperture is in place over the laser head's upper port. Then, follow these steps:

1 **Set the laser head's turret ring to OTHER.**

2 **Visually align the laser head so it is parallel to the machine's travel path. Position it so that the beam strikes the center of the interferometer's window.**

If you cannot see the beam, hold a piece of paper in front of the interferometer.

3 **Adjust the interferometer or translate the laser head so the beam passes through the target's hole and is perpendicular to the interferometer.**

You can adjust the interferometer assembly by moving the spindle up or down or rotating it left or right.

4 **Lock the spindle in place, using, for example, a hose clamp and wedging material. Then, remove the target from the interferometer.**

5 **Gently tap the interferometer assembly to ensure that its mounting is rigid and free of vibration.**

If you feel any vibration, tighten all connections in the mounting.

6 Set the laser head's upper port to the large aperture.

7 Rotate the interferometer's bezel (Figure 5–9) so the scribe line is perpendicular to the reflector's slot.

Two beams should now be exiting the interferometer in a plane perpendicular to the interferometer's slot. The beams appear as dots on the reflector. If you cannot see the beams, hold a piece of paper in front of the reflector.

1 Scribe line
2 Interferometer's window
3 Interferometer's bezel

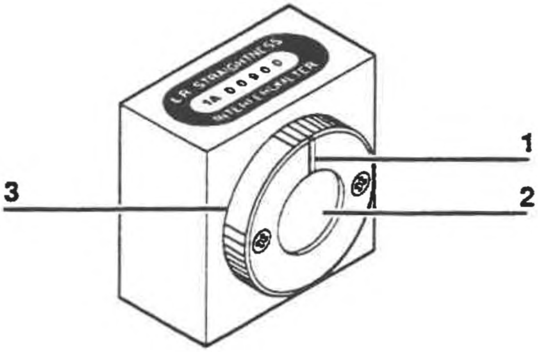


Figure 5–9. Interferometer bezel with scribe line

8 Move the reflector back and forth or side to side until the dots are aligned vertically between the midpoint notches in the reflector's slot (Figure 5–10).

By doing this, you ensure that the beams strike the junction of the two mirrors in the reflector.

1 Reflector's slot
2 Two dots aligned vertically
3 Midpoint notches

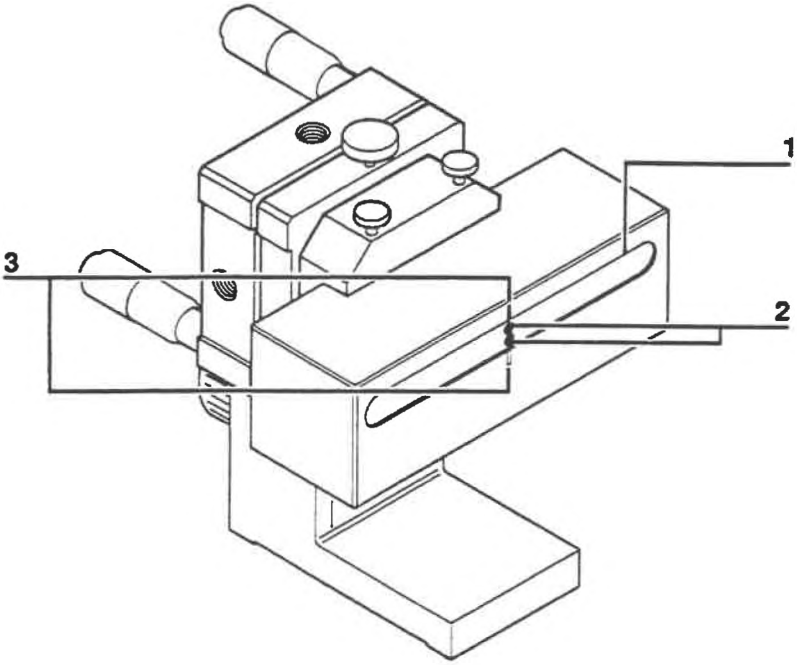


Figure 5–10. Initial position of the dots on the reflector

9 **Set the laser head's upper port to the small aperture and repeat step 8.**

10 **Secure the reflector assembly to the target machine using a clamp or similar device so that the assembly remains perpendicular to the beam.**

When using a clamp to secure the reflector assembly, make sure the base does not rock.

11 **Gently tap the reflector assembly to ensure that its mounting is rigid and free of vibration.**

If you feel any vibration, tighten all connections in the mounting.

You are now ready to align the laser beam to the machine's travel path. Go directly to "Aligning the laser beam to the machine's travel path" later in this chapter.

Making vertical axis straightness measurements

If you have an optical square, you can make a vertical axis straightness measurement as part of a squareness measurement. Follow the instructions in Chapter 7, "Squareness measurements in a vertical plane."

If you do not have an optical square, refer to figures 5–11 through 5–16 for guidance in optical setup and hardware assembly. Adapt the procedure in "Mounting and aligning optics for X-axis or Y-axis measurements" and "Mounting and aligning optics for horizontal Z-axis measurements" as required.

1	Reflector
2	Reflector attachment screws
3	Reflector mount
4	Reflector rotation screw
5	Reflector post
6	Reflector base

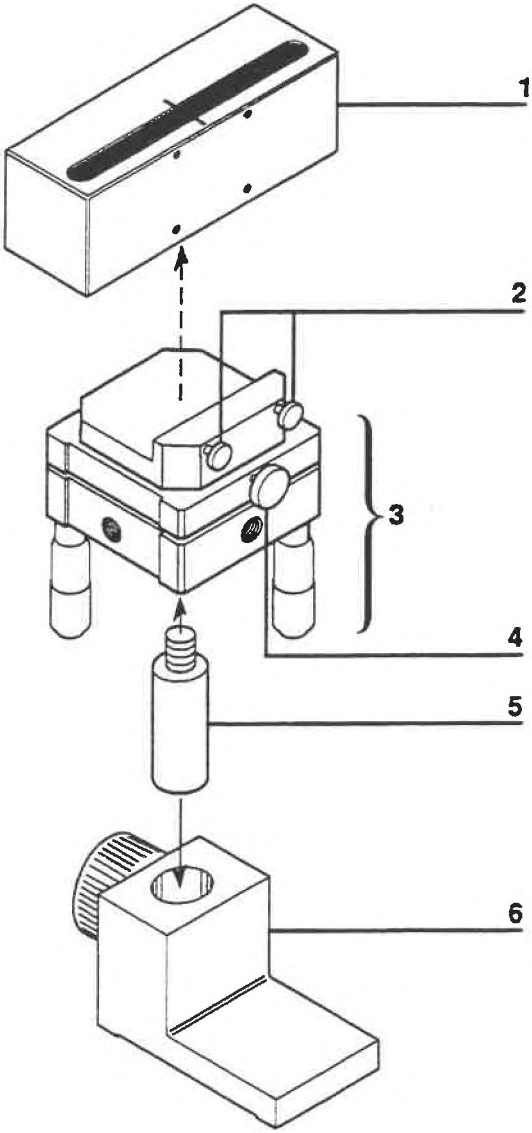


Figure 5–11. Assembling the reflector assembly

1 Turning mirror attachment screws
2 Turning mirror
3 Turning mirror base
4 Turning mirror base attachment screw

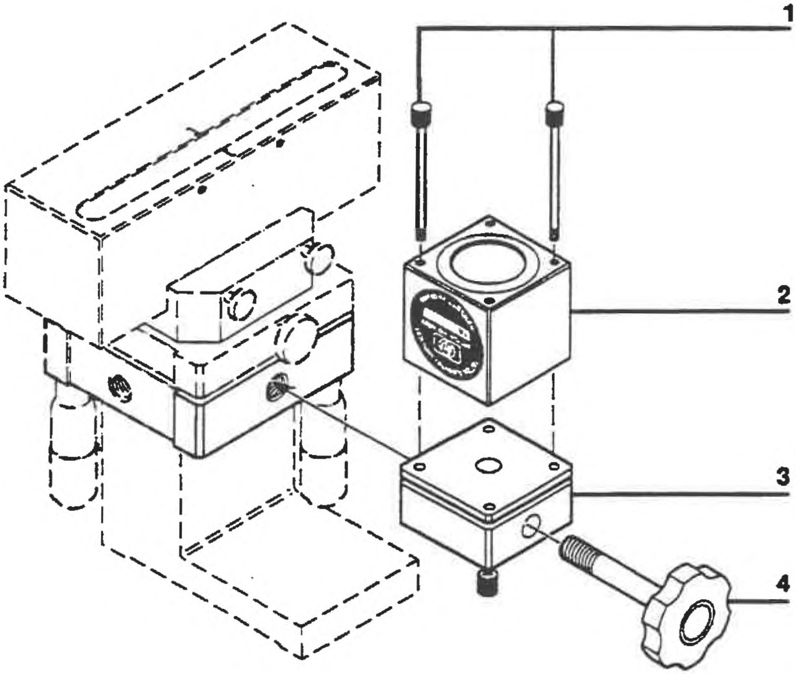


Figure 5–12. Assembling and attaching the turning mirror

1 Attachment screws
2 Retroreflector
3 Interferometer

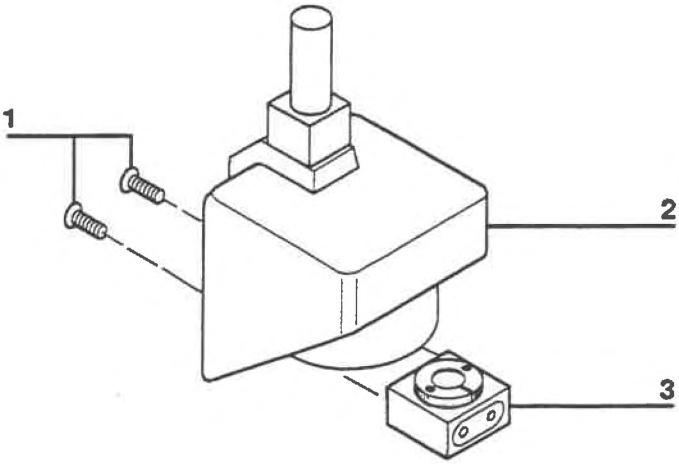


Figure 5–13. Attaching the interferometer to the retroreflector

1 Adjusting screw

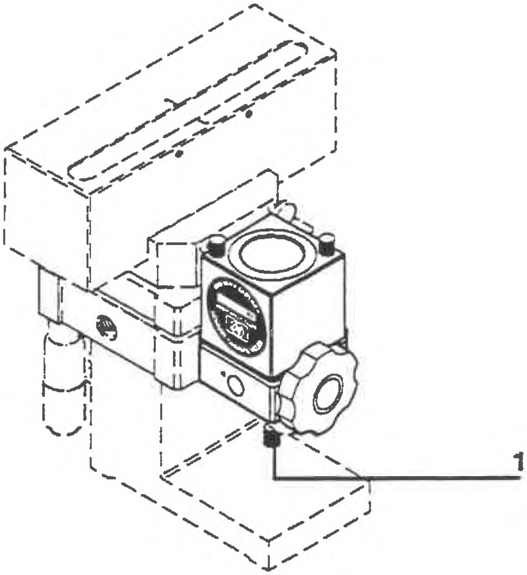


Figure 5–14. Adjusting screw on the turning mirror's base

1 Alignment ring
2 Interferometer
3 Retroreflector

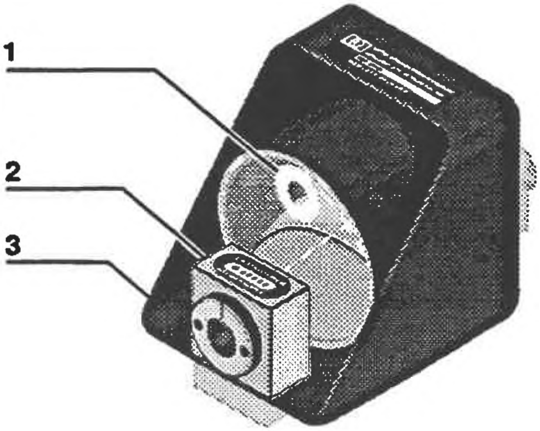


Figure 5–15. Alignment ring on the retroreflector

1 Two dots

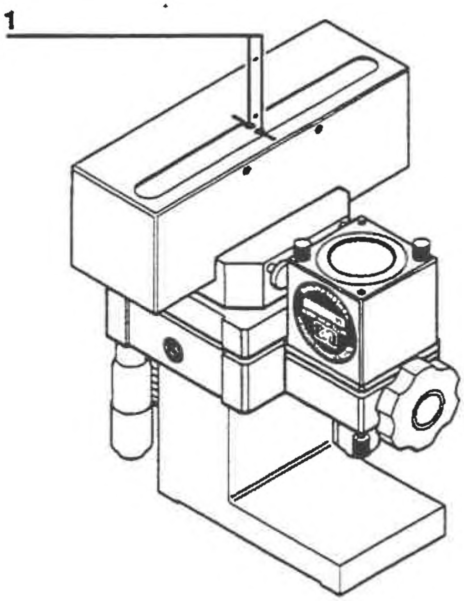


Figure 5–16. Initial position of the dots on the reflector

Aligning the laser beam to the machine's travel path

Before using the following instructions, make sure the turret ring on the laser head is set to OTHER and the small opening is in place over the upper aperture.

To align the laser beam to the machine's travel path, follow these steps:

1 **Attach a target to the moving optic.**

- If the interferometer is the moving optic, attach the round target to the side of the interferometer facing the laser head so the beam passes through the target's hole.
- If the reflector is the moving optic, remove the interferometer. Then, attach the rectangular target to the side of the reflector facing the laser head.

2 **While watching the two dots on the reflector's surface, move the moveable optic away from its initial position.**

As you move the optic, the two dots in the reflector's slot separate (Figure 5–10). Your goal is to make sure that (1) they remain in the plane of the midpoint notches on the reflector, and (2) that both dots remain at an equal distance from the center of the slot.

- If the two dots on the reflector's surface begin to move out of this pattern, tilt the laser head vertically or rotate it left or right to adjust the dots to their correct position.
- If you are using a retroreflector and the beam moves out of the alignment ring on the retroreflector's surface, translate the laser head vertically and horizontally until the beam passes through the alignment ring.

3 **Repeat step 2 until the machine reaches the end of the travel path.**

The laser beam is now aligned to the machine's travel path. Your goal in the rest of this procedure is to ensure the following:

- One beam enters the interferometer.
- Two beams exit the interferometer and strike the two mirrors in the reflector equally spaced from the midpoint notches.
- Two beams enter the interferometer from the reflector.
- One beam enters the lower port on the laser head from the interferometer.

4 **While watching the front of the laser head, rotate the interferometer's bezel so that two dots overlap each other over the lower port on the laser head.**

5 **If you cannot see the dots, follow these steps:**

a In the middle of a piece of paper, cut a round hole the size of the interferometer's lens.

b Place the paper between the reflector and the interferometer, close to the interferometer so that the beams pass through the hole in the paper.

Be sure the paper does not block the beam from the interferometer to the reflector.

You should see either one or two dots on the paper.

c If necessary, adjust the tilt of the reflector using the two large micrometer knobs on the back of the reflector's mounting until the dots disappear into the interferometer.

d Remove the paper.

Two dots now appear on the front of the laser head.

e Slowly turn the interferometer's bezel until the dots overlap.

6 **Adjust the reflector's tilt until the overlapping dots are centered on the laser head's upper port and create a small halo around it.**

7 **Set the laser head's turret ring to STRAIGHT.**

8 **Set the laser head's upper port to the large aperture.**

9 **Slowly turn the bezel until the beam strength displayed on the Set Up Laser: Straightness screen is at least 60 percent.**

Make sure you do not turn the bezel too far.

10 **Adjust the reflector's tilt until you achieve the highest beam strength possible.**

11 **Remove the target from the moveable optic.**

12 **If you had to remove the interferometer, reattach it to its mounting.**

You are now ready to check the alignment for beam strength.

Checking the alignment for beam strength

Before checking the alignment for laser beam strength, ensure that the moveable optic is at its initial position. Then, follow these steps:

1 **Set the laser head's upper port to the large aperture.**

2 **Move the moveable optic along the travel path and check the laser beam strength indicator on the Set Up Laser: Straightness screen.**

If the beam strength is at least 60 percent, go directly to "Making the measurement." If the beam strength indicator falls below 60 percent, ensure the following:

- The reflector is positioned so each of the two beams from the interferometer strike one of the mirrors in the reflector (figure 5–3, 5–4, or 5–5). If they do not, repeat the steps in "Aligning the optics."

- The optics are securely mounted. If are not, remount them and repeat the steps in "Aligning the optics."
- The optics are clean. To clean the optics, follow the directions in the *HP 5529A Getting Started Guide*.

If you used the preceding methods and you still cannot obtain 60 percent beam strength, call your local support person or Hewlett Packard customer support. Refer to the *HP 5529A Getting Started Guide* for a list of Hewlett Packard service and support centers.

Making the measurement

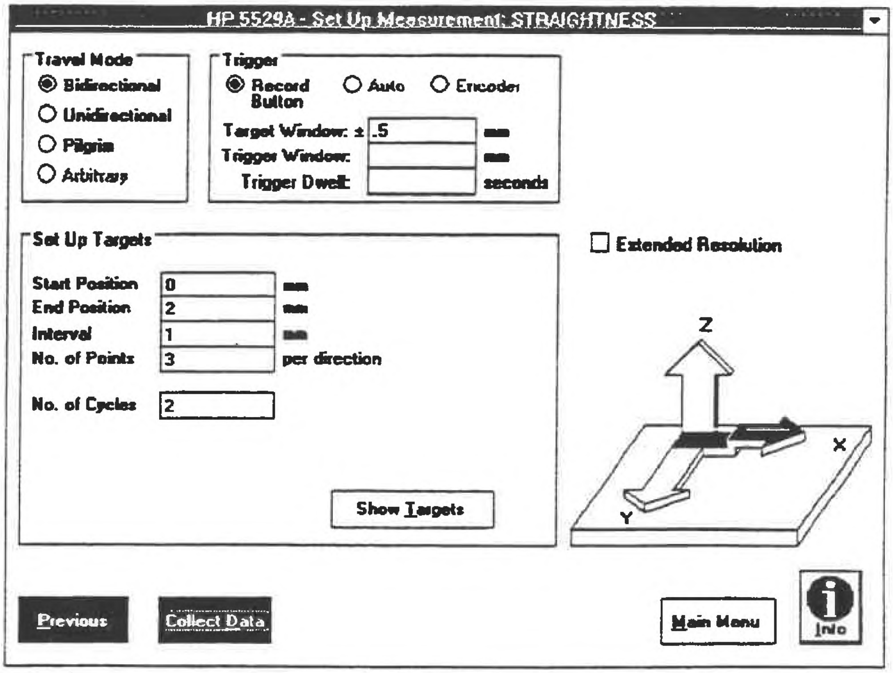
In this procedure, you make manual measurements as you advance the machine's moveable part. The instructions explain how to make measurements using either the Record button displayed on the screen or the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

Note If you have version 1.0 of the metrology software, you cannot rotate the reflector 180 degrees and repeat the measurement as stated in the *HP 5529A Getting Started Guide*. Instead, you will make just one set of measurements.

To make the measurement, follow these steps:

1. **Move the moveable optic so it is at the initial position.**
2. **On the Set Up Laser: Straightness screen, select Set Up Meas.**

   The Set Up Measurement: Straightness screen is displayed (Figure 5-17).



HP 5529A - Set Up Measurement: STRAIGHTNESS

Travel Mode
● Bidirectional
○ Unidirectional
○ Pilgrim
○ Arbitrary

Trigger
● Record Button ○ Auto ○ Encoder
Target Window: ± .5 mm
Trigger Window: mm
Trigger Dwell: seconds

☐ Extended Resolution

Set Up Targets
Start Position 0 mm
End Position 2 mm
Interval 1 mm
No. of Points 3 per direction
No. of Cycles 2

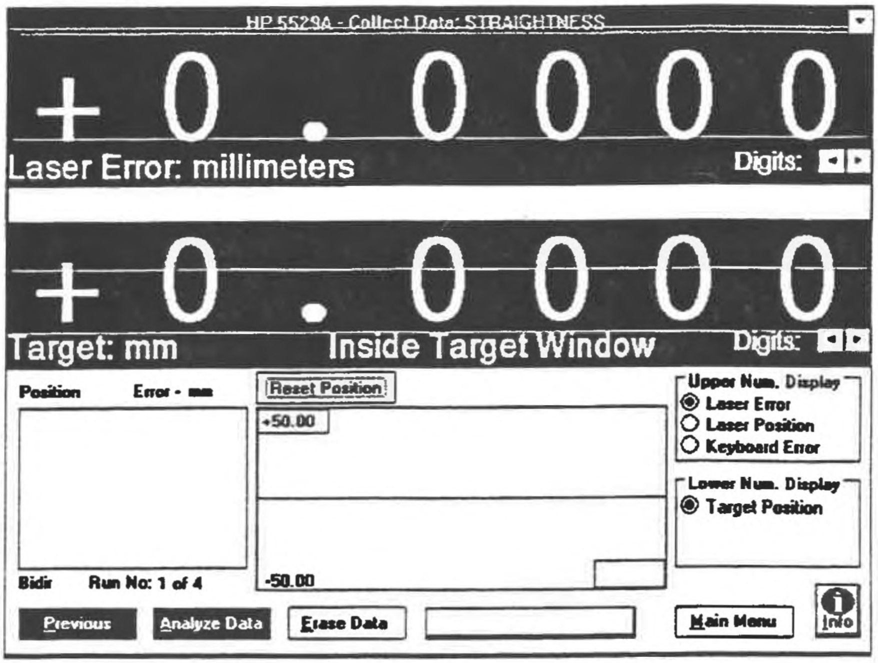
Figure 5–17. Set Up Measurement: Straightness screen

3 **Complete the fields on the Set Up Measurement: Straightness screen.**

If necessary, use the online help.

4 **Select Collect Data.**

The Collect Data: Straightness screen is displayed (Figure 5-18).



HP 5529A - Collect Data: STRAIGHTNESS

+0.0000

Laser Error: millimeters

+0.0000

Target: mm Inside Target Window

Position Error - mm

+50.00

-50.00

Bidir Run No: 1 of 4

Upper Num. Display
● Laser Error
○ Laser Position
○ Keyboard Error

Lower Num. Display
● Target Position

Figure 5–18. Collect Data: Straightness screen

5 **On the Collect Data: Straightness screen, select Reset Position.**

This tells the system that the current position of the reflector is the "zero" point from which all distances will be measured.

If necessary, use the online help to complete the rest of the fields on this screen.

6 **Select Reset Laser.**

This tells the system that the current position of the reflector is the "zero" point, from which all distances will be measured.

7 **Move the machine to the first measurement point.**

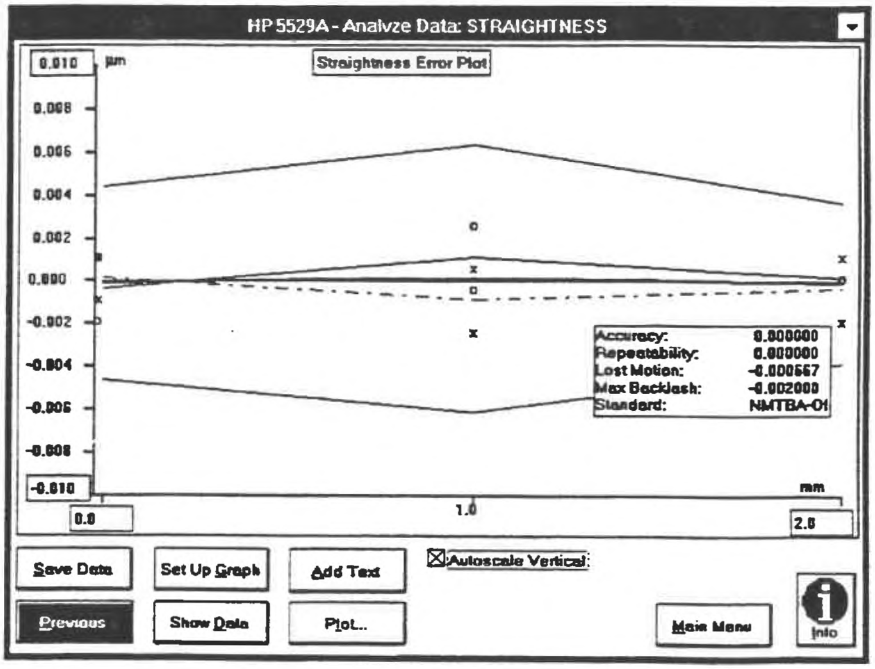
8 **Select Record.**

If you are using the optional remote control unit, press the Record button.

9 **Continue moving the machine to each point and recording measurements until the machine has reached the last measurement position.**

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. Move the retroreflector back to the last position measured before the beam was broken, then select Reset Laser to reset the system.

After you record the last measurement, the Analyze Data: Straightness screen is displayed (Figure 5–19).


HP 5529A - Analyze Data: STRAIGHTNESS
Straightness Error Plot
0.010
µm
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
0.0
1.0
2.0
mm
Save Data
Set Up Graph
Add Text
Previous
Show Data
Plot...
Main Menu
Info

☒ Autoscale Vertical:

Accuracy: 0.000000
Repeatability: 0.000000
Lost Motion: -0.000667
Max Backlash: -0.002000
Standard: NMTBA-01

Figure 5–19. Analyze Data: Straightness screen

10 **Select Save Data to create or update a data file with the measurement data.**

Refer to the HP *5529A Getting Started Guide* for more information about using this screen. Otherwise, you are finished making the measurement.

6. Squareness measurments in a horizontal plane

6. Squareness measurments in a horizontal plane

6

Squareness measurements in a horizontal plane

Squareness measurements in a horizontal plane

This chapter explains how to make squareness measurements in a horizontal plane. These measurements allow you to determine if two machine axes are oriented, and move, perpendicular to each other. An example of a machine with two perpendicular axes is a milling machine with a horizontal spindle and a bed that moves perpendicular to the spindle.

Chapter 7, "Squareness measurements in a vertical plane," explains how to determine if two machine axes that are perpendicular to each other in a *vertical* plane are oriented, and move, perpendicular to each other.

Before performing the procedures described in this chapter, you must fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*. For operating specifications for squareness measurement optics, see Appendix A.

Optical square kit, p/n 10777A

1 Optical square base

2 Optical square

……

Straightness accessory kit, p/n 10776A

3 Reflector mount, p/n 10776-67002

4 Straightness retroreflector, p/n 10776-67001

5 Interferometer base plate, p/n 10776-20011

6 Reflector base and posts

……

Long-range optics kit, p/n 10775A

7 Long-range reflector

8 Long-range interferometer

……

Short-range optics kit, p/n 10774A

9 Short-range reflector

10 Short-range interferometer

……

11 Interferometer target, p/n 10774-67001

……

12 Height adjuster and post, p/n 10785A

13 Reflector target, p/n 10774-20021

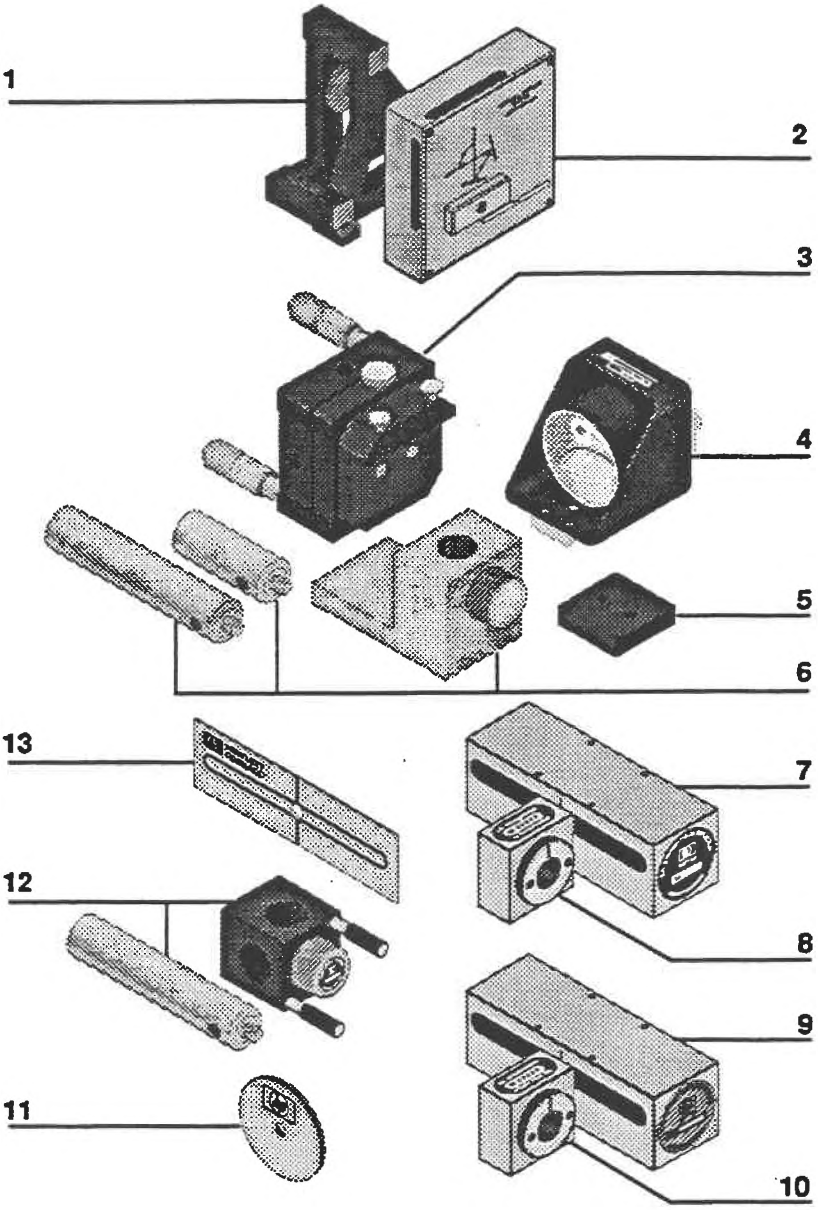


Figure 6–1. Required hardware for squareness measurements in a horizontal plane

Setting up for the measurement

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter to make a squareness measurement. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head, remote control unit, and sensors (if used) to the connectors on the 10886A and 10887A boards installed in the computer.**

The connectors are either on the rear or the side of the computer.

3 **Plug in and turn on all equipment.**

4 **Start the metrology software.**

The Metrology Main Menu is displayed.

5 **On the Metrology Main Menu, select Other Meas.**

The Other Measurements screen is displayed (Figure 6–2).

Alternately, you can open an existing squareness setup file by selecting Recall Data on the Main Menu.

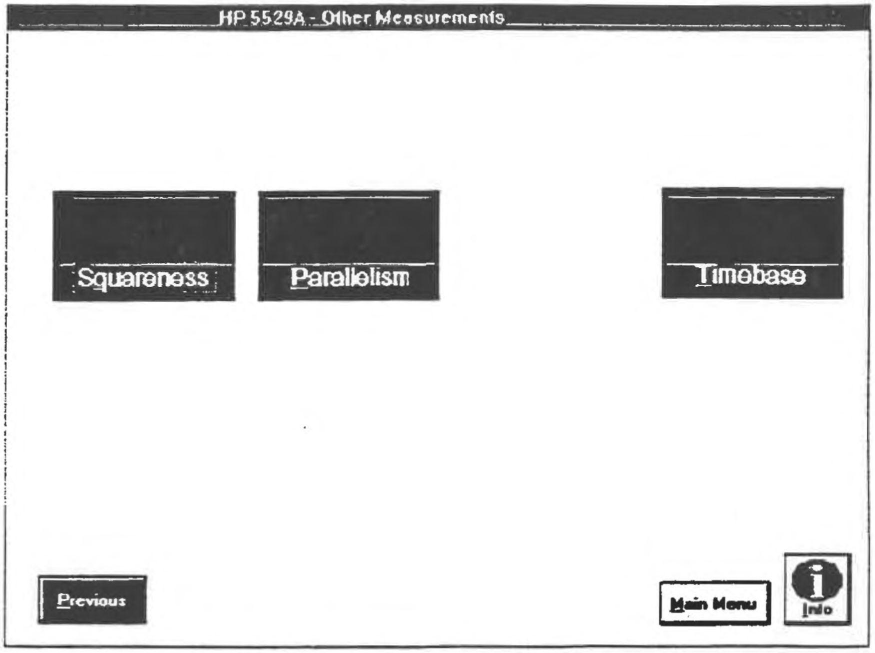

HP 5529A - Other Measurements
Squareness
Parallelism
Timebase
Previous
Main Menu
Info

Figure 6–2. Other Measurements screen

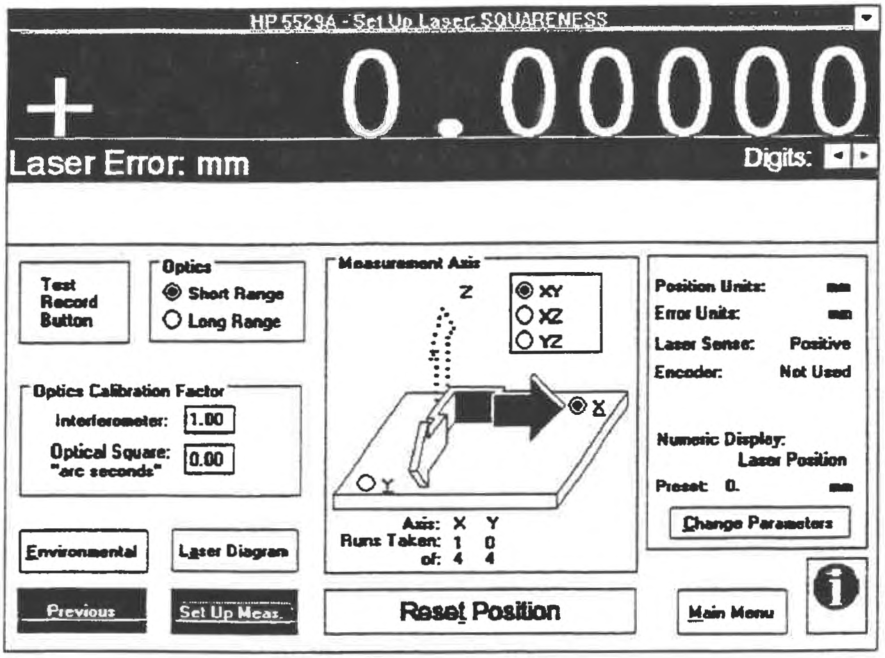
6 **On the Other Measurements screen, select Squareness.**

The Set Up Laser: Squareness screen is displayed (Figure 6–3).

7 **Complete the fields on the Set Up Laser: Squareness screen.**

If necessary, use the online help.

You are now ready to position the laser head and target machine.


HP 5529A - Set Up Laser: SQUARENESS
+ 0.00000
Laser Error: mm
Digits:
Test Record Button
Optics
Measurement Axis
Z
Y
X
Environmental
Laser Diagram
Previous
Set Up Meas.
Reset Position
Main Menu
Change Parameters

Optics: ● Short Range ○ Long Range

Optics Calibration Factor
Interferometer: 1.00
Optical Square: "arc seconds" 0.00

Measurement Axis: ● XY ○ XZ ○ YZ

Axis:	X	Y
Runs Taken:	1	0
of:	4	4

Position Units: mm
Error Units: mm
Laser Sense: Positive
Encoder: Not Used
Numeric Display: Laser Position
Preset: 0. mm

Figure 6–3. Set Up Laser: Squareness screen

Positioning the laser head and target machine

In squareness measurements, you measure the perpendicularity between two axes. You do this by making two straightness measurements. The first axis measurement is a straightness measurement along a horizontal axis (Figure 6–4). You use an optical square for this measurement. The second axis measurement is also a straightness measurement along a horizontal axis. Typically, you do not use an optical square for the second measurement. However, if your machine (such as a CMM) has a stationary bed, you need to use a optical square.

Before you begin to assemble and mount the optics, you must position the laser head and move the moveable part of the target machine to its start position. Follow these steps:

Note This chapter uses a machine with a spindle as an example for making squareness measurements. Although your machine may be different, the general procedures described here still apply.

1 **Position the laser head for the first axis measurement (Figure 6–4 or 6–5).**

The way you position the laser head depends on whether the machine has a vertical or horizontal spindle.

2 **Adjust the laser head to the approximate height at which you will mount the optics.**

3 **Determine how to position the optics. See figure 6–4 or 6–5 for sample setups, and use the following guidelines:**

- A machine with a vertical spindle typically has room to mount both the reflector and the optical square on the table (Figure 6–4). If yours does not, you will need to improvise some kind of table extension.
- Typically, a machine with a horizontal spindle allows you to position the laser head and optics as shown in Figure 6–5.

You are now ready to assemble, mount, and align the optical square and interferometer assembly for the first axis measurement.

1 Reflector oriented horizontally

2 Optical square oriented horizontally

3 Interferometer mounted in a spindle

4 Laser head

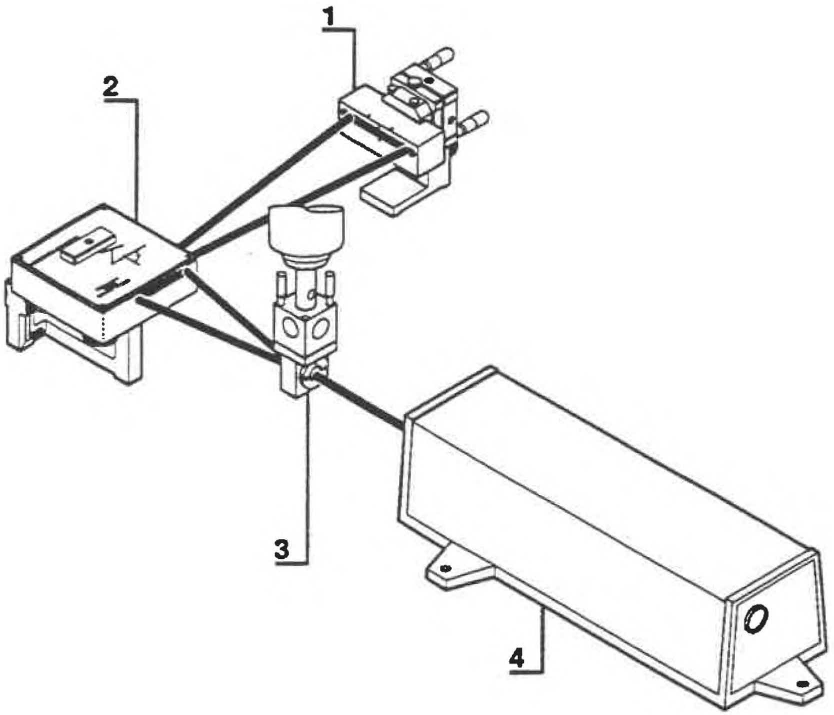


Figure 6–4. First axis positioning of optics on a machine with a vertical spindle

1	**Spindle**
2	**Retroreflector mounted horizontally in a spindle**
3	**Interferometer**
4	**Optical square oriented horizontally**
5	**Laser head**
6	**Reflector oriented horizontally**

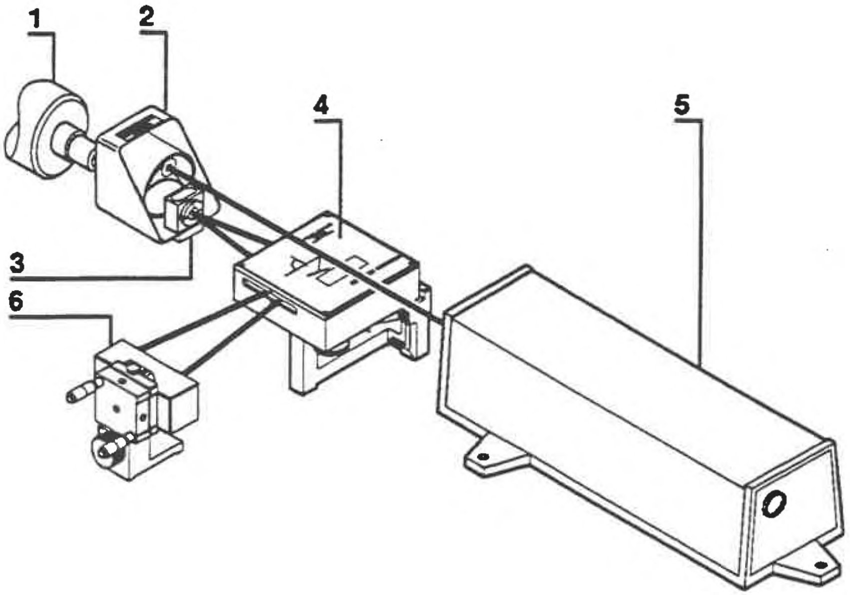


Figure 6–5. First axis positioning of optics on a machine with a horizontal spindle

Mounting and aligning the optical square and interferometer for the first axis measurement

If your machine has a vertical spindle, continue with the instructions in the next section, "Mounting and aligning optics on a machine with a vertical spindle."

If your machine has a horizontal spindle, go directly to the instructions in "Mounting and aligning optics on a machine with a horizontal spindle" in this chapter.

Mounting and aligning optics on a machine with a vertical spindle

This section explains how to assemble, mount, and align the optical square and interferometer on a machine with a vertical spindle.

Mounting the optics

To assemble the optical square and interferometer and mount them on the machine, follow these steps:

1 **Attach the optical square to its mount using the attachment screw (Figure 6–6).**

1	Optical square
2	Slots
3	Optical square mount
4	Attachment screw

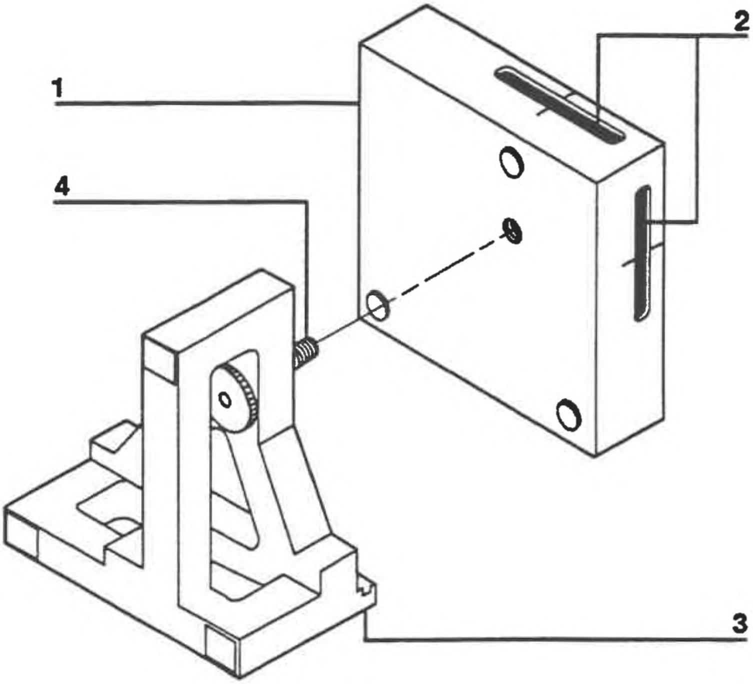


Figure 6–6. Attaching the optical square to its mount

2 **Determine which two axes you will compare for squareness.**

3 **Place the optical square on the target machine as shown in figure 6–4 or 6–5.**

Make sure that each of the optical square's slots points along one of the two measurement axes. Also, make sure you place the square as far down the first axis as possible. This maximizes the amount of the travel path that you will measure.

4 **Connect the interferometer to its base plate using the attachment screws provided (figure 5–6 or 5–7).**

5 **Connect the post to the interferometer using *either* of the following methods (one method uses the height adjuster; the other does not):**

- Remove the large knurled knob from the height adjuster, connect the height adjuster to the interferometer base using the attachment screws, and screw the post into the height adjuster (Figure 5–6). Because this method makes it easier to change optics, use it if you plan to make linear or angular measurements later on.

- Screw the post directly into the interferometer's base plate (Figure 5–7).

6 **Position the interferometer assembly close enough to the optical square to line up the center of the interferometer's window with the midpoint notches on the optical square.**

7 **Orient the interferometer so it is perpendicular to the beam from the laser head.**

8 **Position the optical square so that**

- the side facing the interferometer is parallel to the interferometer

- the optical square is square to the machine

You are now ready to align the optics.

Aligning the optics

To align the optics, follow these steps:

1 **Set the laser head's upper port to the large aperture by turning the upper aperture control (Figure 2–13).**

2 **Set the turret ring to OTHER.**

This provides the highest beam intensity possible.

3 **Visually align the laser head so it is parallel to the machine's table. Position it so that the beam strikes the center of the interferometer's window.**

If you cannot see the beam, hold a piece of paper in front of the interferometer.

4 **Attach the target to the interferometer on the side facing the laser head. Make sure that the edges of the target line up as evenly as possible with the edges of the interferometer's bezel (Figure 5–9).**

5 **Rotate the interferometer's bezel so the scribe line is perpendicular to the reflector's slot.**

Two beams now exit the interferometer in a plane perpendicular to the optical square's slot. If you cannot see the beams, hold a piece of paper in front of the optical square.

6 **Move the optical square back and forth or side to side until the dots are centered between the midpoint notches on the optical square's surface (Figure 6–7).**

1 Two dots

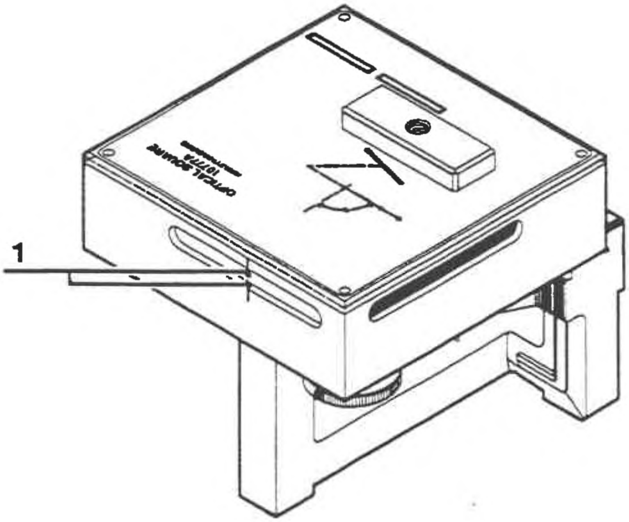


Figure 6–7. Initial position of the dots on the optical square

7 **Secure the optical square to the target machine using a clamp or similar device so that it is perpendicular to the beam from the laser head.**

When using a clamp to secure the optical square, cover as much of the assembly's base as possible with the clamp so the attachment is secure.

8 **Lock the spindle in place using, for example, a hose clamp and wedging material.**

9 **Gently tap the interferometer and optical square assemblies to ensure that their mountings are rigid and free of vibration.**

If you feel any vibration, tighten all connections in the mounting.

You are now ready to go directly to the instructions in "Aligning the laser beam to the machine's travel path."

Mounting and aligning optics on a machine with a horizontal spindle

This section explains how to assemble, mount, and align the optical square, interferometer, and straightness retroreflector on a machine with a horizontal spindle.

Note These procedures include the use of a large *retro*reflector as well as a reflector. The retroreflector is the wedge-shaped optic with the large round window (Figure 6–1).

Mounting the optics

To assemble the optical square and interferometer and mount them on the machine, follow these steps:

1 **Attach the optical square to its mount using the attachment screw (Figure 6–6).**

2 **Determine which two axes you will compare for squareness.**

3 **Place the optical square on the target machine so that it faces, and is in line with, the spindle.**

Make sure that each of the optical square's slots points along one of the two measurement axes. Also, make sure you place the square so as to maximize travel along the axis.

4 **If your machine has T slots that run along to the machine's travel path, place the optical square so its side is parallel to one of the T slots.**

To do this, place two base plates (p/n 10782A) against the edge of a slot and butt the optical square's mount against the base plates. This ensures that the optical square is parallel to the machine's travel path.

5 **Attach the interferometer to the retroreflector using the screws provided (Figure 5–13).**

Throughout the rest of this chapter, this unit is referred to as the "interferometer assembly."

6 **Mount the interferometer assembly on the spindle so that it is as perpendicular as possible to the beam from the laser head.**

7 **Lock the spindle in place using, for example, a hose clamp and wedging material.**

8 **Position the optical square at the near end of travel, close enough to the interferometer assembly to line up the midpoint notches on the optical square with the center of the interferometer's window.**

You are now ready to align the optics.

Aligning the optics

To align the optics, follow these steps:

1 **Set the laser head's upper port to the large aperture by turning the upper aperture control (Figure 2–13).**

2 **Set the turret ring to OTHER.**

This provides the highest beam strength possible.

3 **Visually align the laser head so it is parallel to the machine's table. Position it so that the beam passes over the optical square (Figure 6–5) and through the retroreflector's alignment ring (Figure 5–15).**

You are now ready to align the laser beam to the machine's travel path. Continue with the next section, "Aligning the laser beam to the machine's travel path for the first axis measurement."

Aligning the laser beam to the machine's travel path for the first axis measurement

Before using the following instructions, make sure that the turret ring on the laser head is set to OTHER, the small opening is in place over the upper aperture, and the optical square is square to the machine. To ensure that the optical square is square to the machine, you can use T slots (if available) or a dial indicator.

To align the laser beam to the machine's travel path, follow these steps:

1 **Place a gauge block on the optical square.**

- If your optics are set up as shown in Figure 5–4, place the gauge block over the midpoint notches on the optical square on the side facing the laser head. To secure the gauge block, you can use a rubber band. Then, remove the interferometer from its base plate.
- If your optics are set up as shown in Figure 5–5, place the gauge block over the midpoint notches on the optical square on the side facing the retroreflector. Then, remove the interferometer from the retroreflector.

2 **Rotate or translate the laser head until the beam reflects off the gauge block and enters the upper port on the laser's head.**

3 **Remount the interferometer.**

You are now ready to mount and align the reflector for the first axis measurement.

Mounting and aligning the reflector for the first axis measurement

This section explains how to mount and align the reflector for first axis measurements for machines with a horizontal *or* vertical spindle.

Mounting the reflector

To assemble and mount the reflector on the machine, follow these steps:

1 **Assemble the reflector and its mounting hardware as shown in Figure 5–8.**

Position the reflector so the slot is closest to the top edge.

2 **Place the reflector assembly on the target machine as shown in figure 6–4 or 6–5.**

Aligning the reflector

Before using the following procedures, make sure that

- the turret ring on the laser head is set to OTHER
- the small opening is in place over the upper aperture and
- the scribe line on the interferometer's bezel is perpendicular to the optical square's slot
- the optics are at the start position

To align the reflector, follow these steps:

1 **Move the optics close enough together so that the two dots pass through the slot on the optical square on the side facing the interferometer.**

2 **Place the reflector at the end of the second axis (figure 6–4 or 6–5).**

3 **Move the reflector back and forth or side to side until the two beams from the optical square overlay the midpoint notches on the reflector.**

The dots overlay the notches the same as they did on the optical square when you were aligning it (Figure 6–8).

If you cannot get the two dots to strike the front of the reflector, remove the interferometer and move the reflector back and forth or side to side until the single beam from the optical square overlays the midpoint notches on the reflector.

4 **If necessary, reattach the interferometer to the spindle.**

5 **Rotate the reflector left or right so that it is perpendicular to the optical square.**

6 **Secure the reflector to the machine using a clamp or similar device so that the assembly remains perpendicular to the beam.**

When using a clamp to secure the reflector, cover as much of the assembly's base as possible with the clamp so the attachment is secure.

Your goal in the rest of this procedure is to center the two return beams on the laser head's upper port.

7 **Turn the interferometer's bezel so that the scribed line is parallel to the optical square's slot.**

Two overlapping dots should now appear on the side of the optical square facing the reflector.

If you cannot see the dots, adjust the tilt of the reflector using the two micrometer knobs on the back of the reflector mount until you see the dots on the optical square.

8 **Turn the interferometer's bezel until the two dots are parallel to the slot in the optical square.**

9 **Adjust the tilt of the reflector (using the two micrometer knobs on the back of the reflector) mount until the dots**

- appear on the surface of the optical square (Figure 6–8)
- are at an equal distance from the midpoint notches

1 Two dots

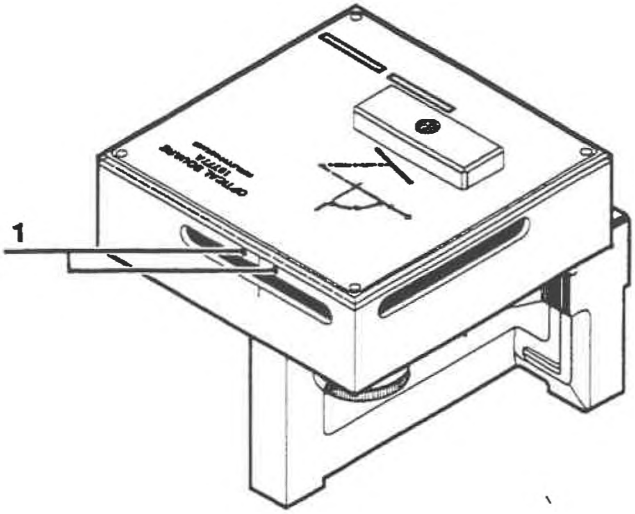


Figure 6–8. Position of the two dots after adjusting the reflector

10 Adjust the tilt of the reflector (using the micrometer knobs on the back of the reflector mount) until the dots disappear into the slot on the optical square.

Two dots now appear on the front panel of the laser head. If you cannot see the dots, it is because the beams from the optical square are not entering the interferometer. To correct this problem, follow these steps:

a Look at the side of the interferometer facing the optical square.

You should see one dot or two dots very close together on the face of the interferometer.

b Adjust the tilt of the reflector (using the two micrometer knobs on the back of the reflector's mount) until the dots disappear into the interferometer's window.

You should see the dot(s) on the front of the laser head.

11 **If you see one dot, go directly to step 12. If you see two dots, slowly turn the bezel until they overlap. Then go to step 12.**

12 **Adjust the reflector's tilt until the overlapping dots are centered on the exit port and create a small halo around it.**

13 **Set the laser head's turret ring to STRAIGHT.**

14 **Set the laser head's upper port to the large aperture.**

15 **Turn the bezel slightly until the beam strength displayed on the Set Up Laser: Squareness screen is at least 60 percent.**

16 **Adjust the tilt until you achieve the highest beam strength possible.**

You are now ready to check the alignment for beam strength.

Checking the alignment for beam strength for the first axis measurement

Follow the instructions in "Checking the alignment for beam strength" in Chapter 5.

You are now ready to make the first axis measurement.

Making the first axis measurement

In this procedure, you will make manual measurements as you advance the machine's moveable part. The instructions explain how to make measurements using either the Record button displayed on the screen or the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

To make the squareness measurement for the first axis, follow these steps:

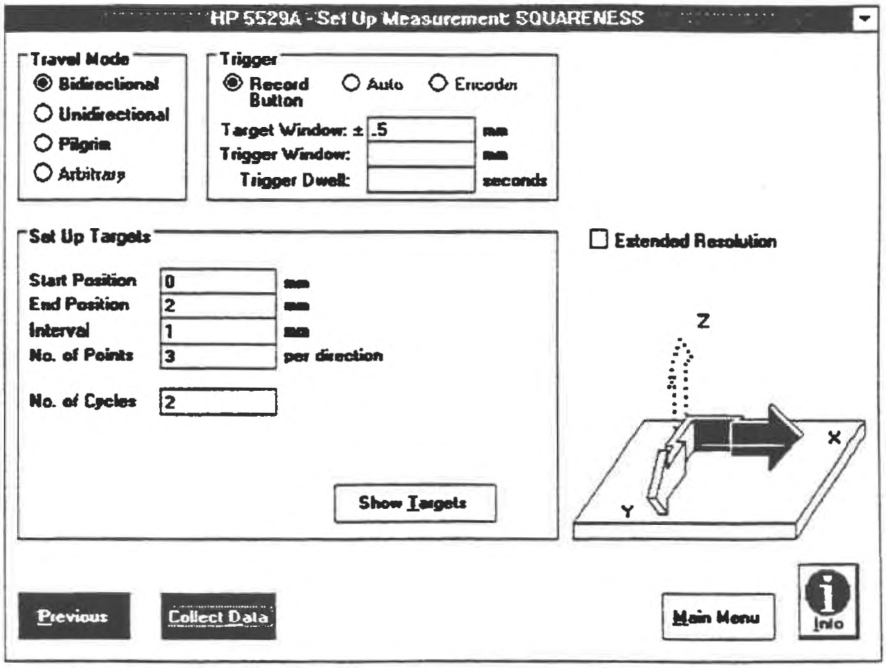
1 **Move the moveable optic so it is at the start position.**

2 **On the Set Up Laser: Squareness screen, do the following:**

- **In the Measurement Axis box, select the pair of axes that you are measuring for squareness.**
- **In the Measurement Axis box, select the axis you will measure first.**

3 **Select Set Up Meas.**

The Set Up Measurement: Squareness screen is displayed (Figure 6-9).



HP 5529A - Set Up Measurement SQUARENESS

Travel Mode
● Bidirectional
○ Unidirectional
○ Pilgrim
○ Arbitrary

Trigger
● Record Button
○ Auto
○ Encoder
Target Window: ± .5 mm
Trigger Window: mm
Trigger Dwell: seconds

☐ Extended Resolution

Set Up Targets
Start Position 0 mm
End Position 2 mm
Interval 1 mm
No. of Points 3 per direction
No. of Cycles 2

Figure 6–9. Set Up Measurement: Squareness screen

4 **Complete the fields on the Set Up Measurement: Squareness screen.**

If necessary, use the online help.

5 **Select Collect Data.**

The Collect Data: Squareness screen is displayed (Figure 6-10).

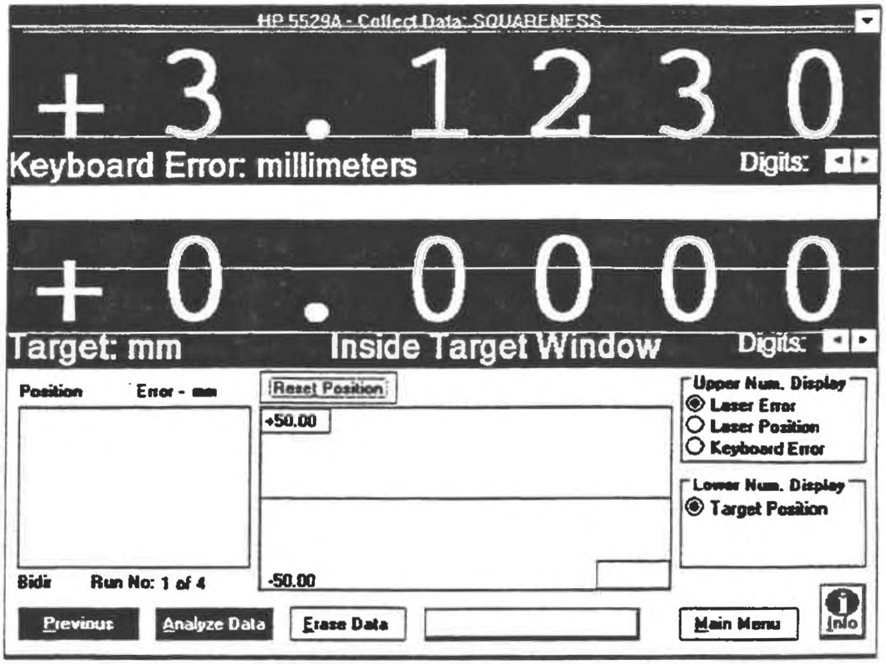

HP 5529A - Collect Data: SQUARENESS
+3.1230
Keyboard Error: millimeters
Digits:
+0.0000
Target: mm
Inside Target Window
Digits:
Position
Error - mm
Reset Position
+50.00
-50.00
Bidir
Run No: 1 of 4
Upper Num. Display
● Laser Error
○ Laser Position
○ Keyboard Error
Lower Num. Display
● Target Position
Previous
Analyze Data
Erase Data
Main Menu
Info

Figure 6–10. Collect Data: Squareness screen

6 **Complete the fields on the Collect Data: Squareness screen.**

If necessary, use the online help.

7 **Select Reset Laser.**

This tells the system that the current position of the reflector is the "zero" point, from which all distances will be measured.

8 **Move the machine to the first measurement point.**

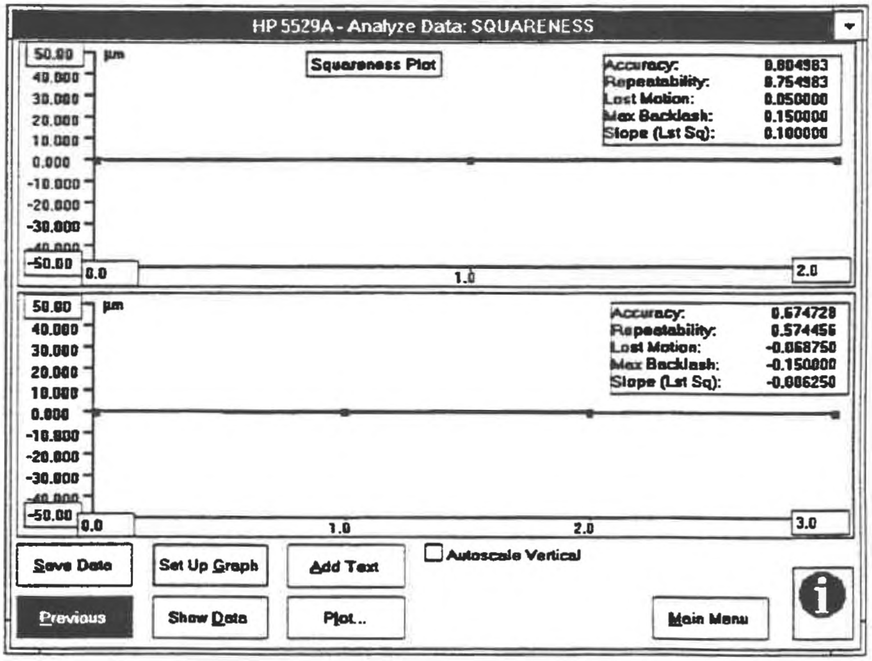
9 **Select Record.**

If you are using the optional remote control unit, press the Record button.

10 **Continue moving the machine to each point and recording measurements until you are finished.**

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. Select Reset Laser to reset the system, then move the retroreflector back to the last position measured before the beam was broken.

After you record the last measurement, the Analyze Data: Squareness screen is displayed (Figure 6–11).



HP 5529A - Analyze Data: SQUARENESS

Accuracy: 0.804983
Repeatability: 0.754983
Lost Motion: 0.050000
Max Backlash: 0.150000
Slope (Lst Sq): 0.100000

Accuracy: 0.674728
Repeatability: 0.574456
Lost Motion: -0.068750
Max Backlash: -0.150000
Slope (Lst Sq): -0.006250

Squareness Plot
50.00
40.000
30.000
20.000
10.000
0.000
-10.000
-20.000
-30.000
-40.000
-50.00
µm
0.0
1.0
2.0
3.0
☐ Autoscale Vertical
Save Data
Set Up Graph
Add Text
Previous
Show Data
Plot...
Main Menu

Figure 6–11. Analyze Data: Squareness screen

11 On the Analyze Data: Squareness screen, select Next Axis.

You are returned to the Set Up Laser: Squareness screen.

You are now ready to mount and align optics for the second axis measurement.

Mounting and aligning optics for the second axis measurement

Use this procedure to mount and align optics for machines with a horizontal *or* a vertical spindle.

The second axis measurement is simply a horizontal straightness measurement along the axis on which you previously mounted the reflector.

CAUTION Do not move or adjust the reflector while preparing for or making the second axis measurement. The reflector is the reference for the squareness measurement. If you move the reflector, you lose your reference.

To mount and align optics for the second axis measurement, follow these steps:

1. **Remove the optical square and, for machines with a horizontal spindle, the interferometer assembly.**

   Do not move or adjust the reflector.

2. **Move the laser head so it is oriented along the second axis (figure 6–12 or 6–13).**

3. **Adjust the laser head so the beam is centered between the reflector's midpoint notches.**

4. **Follow the instructions in "Mounting and aligning optics for X-axis or Y-axis measurements" in Chapter 5.**

CAUTION Do not try to align the laser beam to the travel path of the second axis as instructed at the end of "Mounting and aligning optics for X–axis or Y–axis measurements" in Chapter 5. If you do, the software will not be able to calculate squareness between the two axes. Instead, go directly to "Checking the alignment for beam strength" in this chapter.

- If your machine has a horizontal spindle, you assemble and mount the interferometer assembly horizontally as shown in Figure 6–13 instead of vertically as specified in Chapter 5. Even though the alignment procedures in Chapter 5 are for machines with a vertical spindle, you can still use them to align the optics on your machine.

- If your machine has a vertical spindle, ignore instructions in Chapter 5 for assembling and mounting the interferometer since you have already done so. Instead, move the spindle so it is between the laser head and the reflector, and go directly to "Aligning the optics" in "Mounting and aligning optics for X–axis or Y–axis measurements" in Chapter 5.

1 Reflector oriented horizontally
2 Interferometer mounted in a spindle
3 Laser head

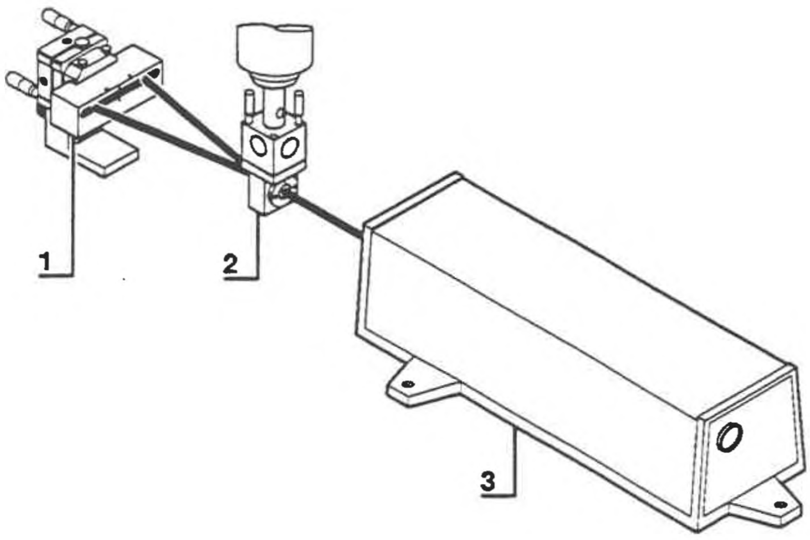


Figure 6–12. Second axis positioning of optics on a machine with a vertical spindle

1	Spindle
2	Laser head
3	Interferometer mounted in a spindle
4	Reflector oriented horizontally

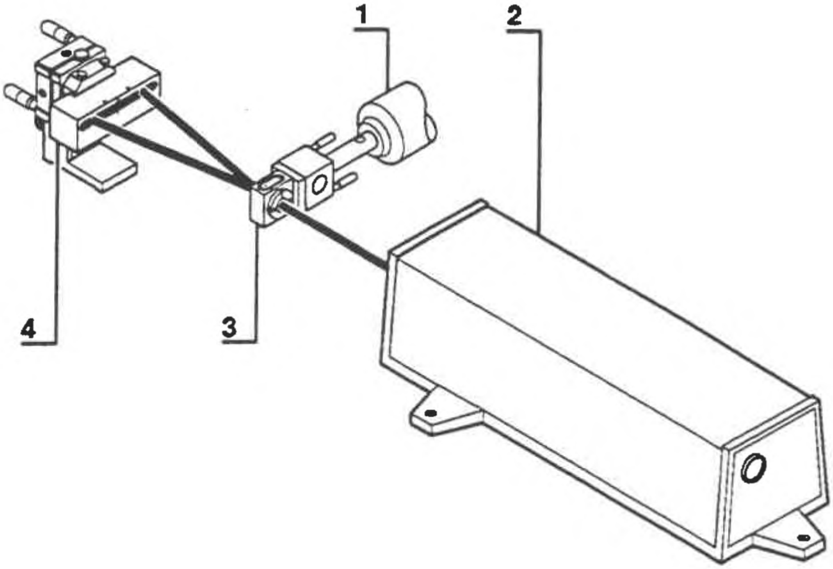


Figure 6–13. Second axis positioning of optics on a machine with a horizontal spindle

Aligning the laser beam to the machine's travel path for the second axis measurement

Follow the instructions in "Aligning the laser beam to the machine's travel path" in Chapter 5. Remember, *do not* move or adjust the reflector.

You are now ready to check the alignment for beam strength.

Checking the alignment for beam strength for the second axis measurement

Follow the instructions in "Checking the alignment for beam strength" in Chapter 5. Remember, *do not* move or adjust the reflector.

You are now ready to make the second axis measurement.

Making the second axis measurement

To make the second axis measurement, follow these steps:

1 **On the Set Up Laser: Squareness screen, select the second axis you are measuring.**

2 **Repeats steps 3 through 10 in "Making the first axis measurement."**

After you record the last measurement, the Analyze Data: Squareness screen is displayed (Figure 6–11).

Refer to the *HP 5529A Getting Started Guide* and online help for more information about using this screen.

3 **Select Save Data to create or update a data file with the measurement data.**

Otherwise, you are finished making the measurement.

7. Squareness measurements in a vertical plane

7. Squareness measurements in a vertical plane

7

Squareness measurements in a vertical plane

Squareness measurements in a vertical plane

This chapter explains how to make squareness measurements in a vertical plane. These measurements allow you to determine if two machine axes are oriented, and move, perpendicular to each other. An example of a machine with two perpendicular axes is a Coordinate Measurement Machine (CMM) with a probe that moves vertically, mounted on a bridge that moves horizontally.

Chapter 6, "Squareness measurements in a horizontal plane," explains how to determine if two machine axes that are perpendicular to each other in a horizontal plane are oriented, and move, perpendicular to each other.

Before performing the procedures described in this chapter, you must fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*. For operating specifications for squareness measurement optics, see Appendix A.

Optical square kit, p/n 10777A

1 Optical square base
2 Optical square

* * *

Straightness accessory kit, p/n 10776A

3 Reflector mount, p/n 10776-67002
4 Straightness retroreflector, p/n 10776-67001
5 Reflector base and posts, p/n 10776-67008

* * *

Long-range optics kit, p/n 10775A

6 Long-range reflector
7 Long-range interferometer

* * *

Short-range optics kit, p/n 10774A

8 Short-range reflector
9 Short-range interferometer

* * *

10 Height adjuster and post, p/n 10785A

* * *

Turning mirror kit, p/n 10772A

11 Turning mirror
12 Turning mirror base
13 Reflector target, p/n 10774-20021

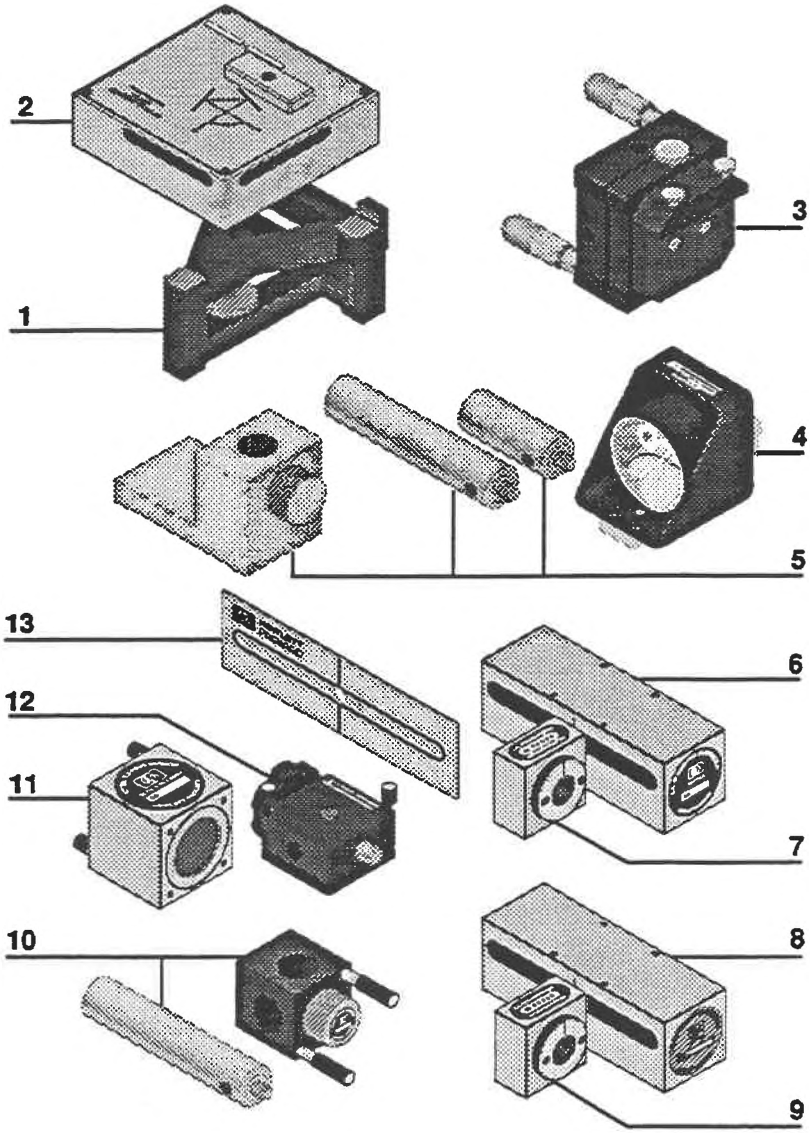


Figure 7–1. Required hardware for squareness measurements in a vertical plane

Setting up for the measurement

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter to make a squareness measurement. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head, remote control unit, and sensors (if used) to the connectors on the 10886A and 10887A boards installed in the computer.**

The connectors are either on the rear or the side of the computer.

3 **Plug in and turn on all equipment.**

4 **Start the metrology software.**

The Metrology Main Menu is displayed.

6 **On the Metrology Main Menu, select Other Meas.**

The Other Measurements screen is displayed (Figure 7–2).

Alternately, you can open an existing squareness setup file by selecting Recall Data on the Main Menu.

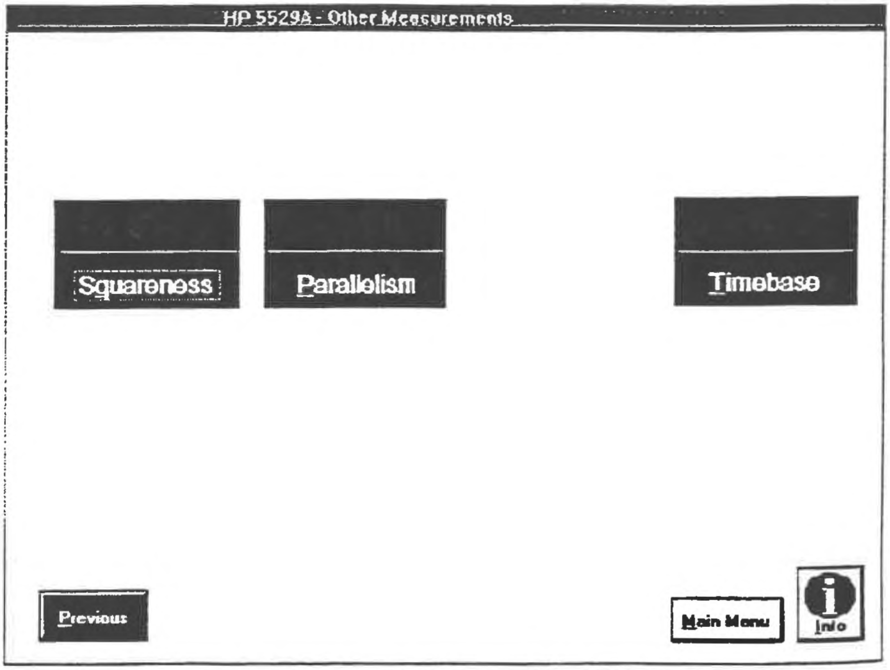

HP 5529A - Other Measurements
Squareness
Parallelism
Timebase
Previous
Main Menu
Info

Figure 7–2. Other Measurements screen

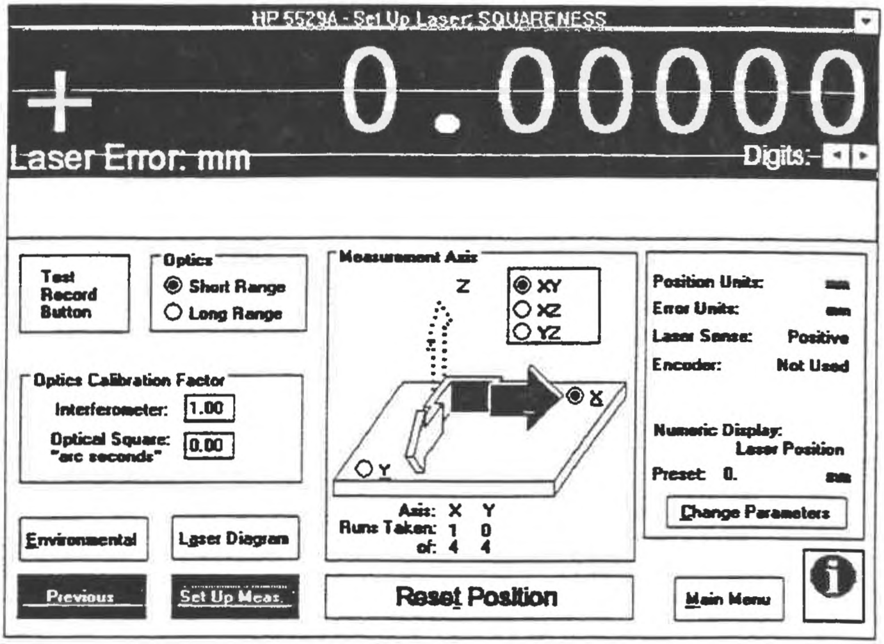
7 **On the Other Measurements screen, select Squareness.**

The Set Up Laser: Squareness screen is displayed (Figure 7–3).

8 **Complete the fields on the Set Up Laser: Squareness screen.**

If necessary, use the online help.

You are now ready to position the laser head and target machine.



HP 5529A - Set Up Laser: SQUARENESS

+ 0.00000

Laser Error: mm

Optics: ● Short Range ○ Long Range

Optics Calibration Factor
Interferometer: 1.00
Optical Square: "arc seconds" 0.00

Measurement Axis: ● XY ○ XZ ○ YZ

● X ○ Y

Axis: X Y
Runs Taken: 1 0
of: 4 4

Position Units: mm
Error Units: mm
Laser Sense: Positive
Encoder: Not Used
Numeric Display: Laser Position
Preset: 0. mm

Figure 7–3. Set Up Laser: Squareness screen

Positioning the laser head and target machine

In squareness measurements, you measure the perpendicularity between two axes. You do this by making a straightness measurement along each of the two axes. The first axis measurement is a straightness measurement along a horizontal axis (figures 5–3, 5–4, and 5–5). In this measurement, you use a reflector assembly and an interferometer assembly. The second axis measurement is a straightness measurement along the axis perpendicular to the first axis. In this measurement, you use the reflector assembly, an optical square/turning mirror assembly, and an interferometer/retroreflector assembly (Figure 7–9).

Before you begin to assemble and mount the optics, you must position the laser head and move the moveable part of the target machine to its start position. Follow these steps:

Note This chapter uses a machine with a spindle as an example for making squareness measurements. Although your machine may be different, the general procedures described here still apply.

1 **Position the laser head for the first axis measurement (Figure 5–3).**

2 **Adjust the laser head to the approximate height at which you will mount the optics.**

3 **Determine how to position the optics. See Figure 5–3 for an illustration of the optics setup, and use the following guidelines:**

- Mount the combined retroreflector/interferometer where the tool mounts.
- Mount the reflector where the workpiece mounts.

You are now ready to mount and align the optics for the first axis measurement.

Mounting and aligning the optics for the first axis measurement

This section explains how to assemble, mount, and align the optics for the first axis measurement. Follow these steps:

1 **Complete steps 1 through 5 in "Mounting and aligning optics for X-axis or Y-axis measurements" in Chapter 5.**

Keep in mind that the first axis measurement is a measurement in a vertical plane along the X-axis.

Place the reflector as far down the first axis as possible. This maximizes the amount of the travel path that you will measure, ensuring a more accurate measurement.

2 **Attach the optical square to its mount using the attachment screw (Figure 6–6).**

3 **Place the optical square *vertically* on the machine close to the reflector assembly. Then line up the midpoint notches on the reflector with the midpoint notches on the optical square.**

To line up the notches, adjust the height of the reflector by loosening the large knob on the height adjuster, moving the interferometer up or down, then tightening the knob.

4 **Remove the optical square from the machine.**

5 **Place the reflector assembly on the target machine as shown in Figure 5–3. Make sure the reflector assembly is no closer to the interferometer than**

- 100 mm (4 inches) for *short-range* measurements
- 900 mm (36 inches) for *long-range* measurements

This ensures that the two beams from the interferometer strike the reflector properly. Each of the two beams must strike one of the mirrors in the reflector (figure 5–3, 5–4, or 5–5).

Note Although the mounting assembly provided with the reflector provides considerable mounting flexibility, there may be some situations when you need added flexibility. Figure 2–12 shows how you can use additional hardware to increase flexibility.

6 **Complete the steps in "Aligning the optics" in "Mounting and aligning optics for X-axis or Y-axis measurements" in Chapter 5.**

You are now ready to align the laser beam to the machine's travel path.

Aligning the laser beam to the machine's travel path for the first axis measurement

Follow the instructions in "Aligning the laser beam to the machine's travel path" in Chapter 5. (Although Chapter 5 refers to straightness software screens instead of squareness screens, the instructions still apply.)

You are now ready to check the alignment for beam strength.

Checking the alignment for beam strength for the first axis measurement

Follow the instructions in "Checking the alignment for beam strength" in Chapter 5. (Although Chapter 5 refers to straightness software screens instead of squareness screens, the instructions still apply.)

You are now ready to make the first axis measurement.

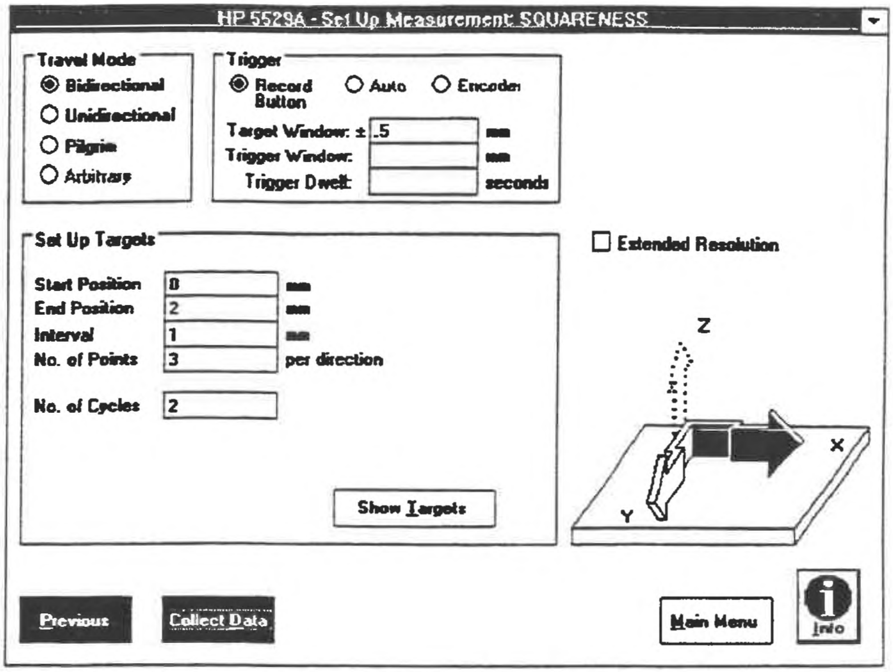
Making the first axis measurement

In this procedure, you will make manual measurements as you advance the machine's moveable part. The instructions explain how to make measurements using either the Record button displayed on the screen or the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

To make the first axis measurement, follow these steps:

1. **Move the moveable optic so it is at the start position.**
2. **On the Set Up Laser: Squareness screen, do the following:**
   - In the Measurement Axis box, select the pair of axes that you are measuring for squareness.
   - In the Measurement Axis box, select the pair of axes that you will measure first.
3. **Select Set Up Meas.**

   The Set Up Measurement: Squareness screen is displayed (Figure 7-4).


HP 5529A - Set Up Measurement: SQUARENESS
Show Targets
☐ Extended Resolution
Z
X
Y
Previous
Collect Data
Main Menu
Info

Travel Mode
● Bidirectional
○ Unidirectional
○ Pilgrim
○ Arbitrary

Trigger
● Record Button ○ Auto ○ Encoder
Target Window: ± .5 mm
Trigger Window: mm
Trigger Dwell: seconds

Set Up Targets
Start Position 0 mm
End Position 2 mm
Interval 1 mm
No. of Points 3 per direction
No. of Cycles 2

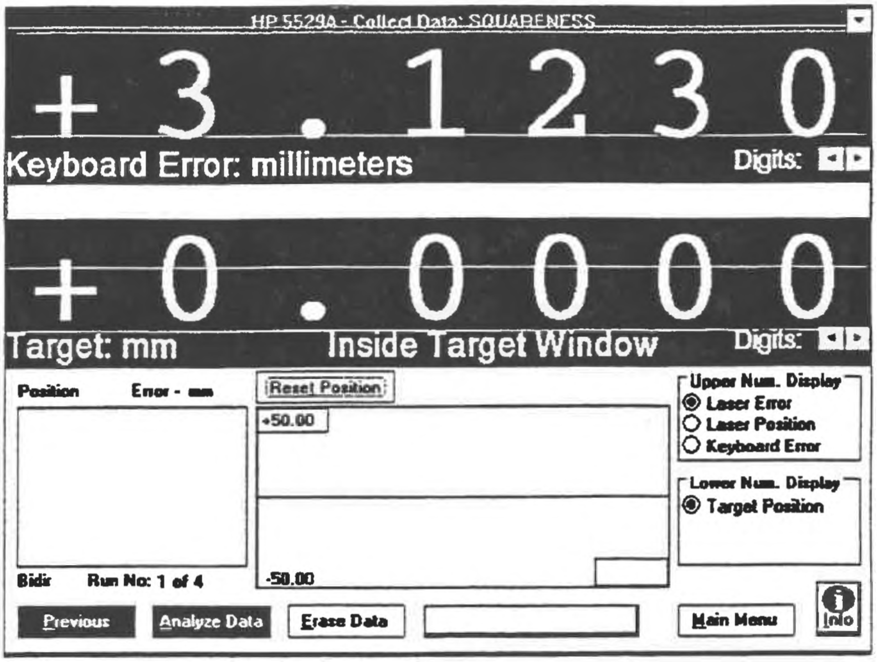
Figure 7–4. Set Up Measurement: Squareness screen

4 **Complete the fields on the Set Up Measurement: Squareness screen.**

If necessary, use the online help.

5 **Select Collect Data.**

The Collect Data: Squareness screen is displayed (Figure 7-5).



HP 5529A - Collect Data: SQUARENESS

+3.1230

Keyboard Error: millimeters

+0.0000

Target: mm

Inside Target Window

Upper Num. Display
● Laser Error
○ Laser Position
○ Keyboard Error

Lower Num. Display
● Target Position

Bidir Run No: 1 of 4

Digits:
Digits:
Position
Error - mm
Reset Position
+50.00
-50.00
Previous
Analyze Data
Erase Data
Main Menu
Info

Figure 7–5. Collect Data: Squareness screen

6 **Complete the fields on the Collect Data: Squareness screen.**

If necessary, use the online help.

7 **Select Reset Laser.**

This tells the system that the current position of the reflector is the “zero” point, from which all distances will be measured.

8 **Move the machine to the first measurement point.**

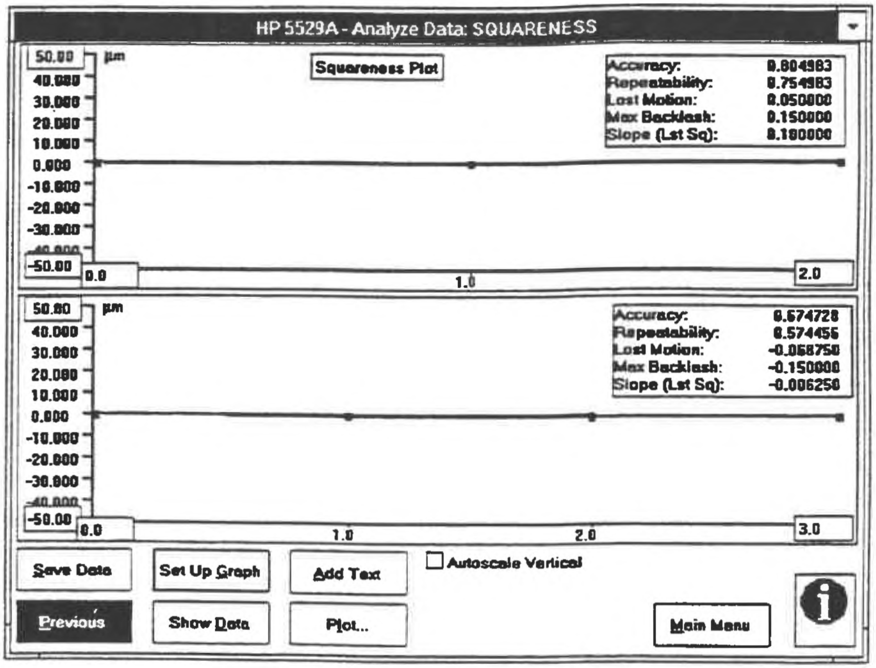
9 **Select Record.**

If you are using the optional remote control unit, press the Record button.

10 **Continue moving the machine to each point and recording measurements until you are finished.**

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. Select Reset Laser to reset the system, then move the reflector back to the zero position.

After you record the last measurement, the Analyze Data: Squareness screen is displayed (Figure 7–6).


HP 5529A - Analyze Data: SQUARENESS
Squareness Plot
50.00
40.000
30.000
20.000
10.000
0.000
-10.000
-20.000
-30.000
-40.000
-50.00
µm
0.0
1.0
2.0
3.0
Save Data
Set Up Graph
Add Text
☐ Autoscale Vertical
Previous
Show Data
Plot...
Main Menu

Accuracy: 0.804983
Repeatability: 0.754983
Lost Motion: 0.050000
Max Backlash: 0.150000
Slope (Lst Sq): 0.180000

Accuracy: 0.674728
Repeatability: 0.574455
Lost Motion: -0.068750
Max Backlash: -0.150000
Slope (Lst Sq): -0.006250

Figure 7–6. Analyze Data: Squareness screen

11 On the Analyze Data: Squareness screen, select Next Axis.

You are returned to the Set Up Laser: Squareness screen.

You are now ready to mount and align optics for the second axis measurement.

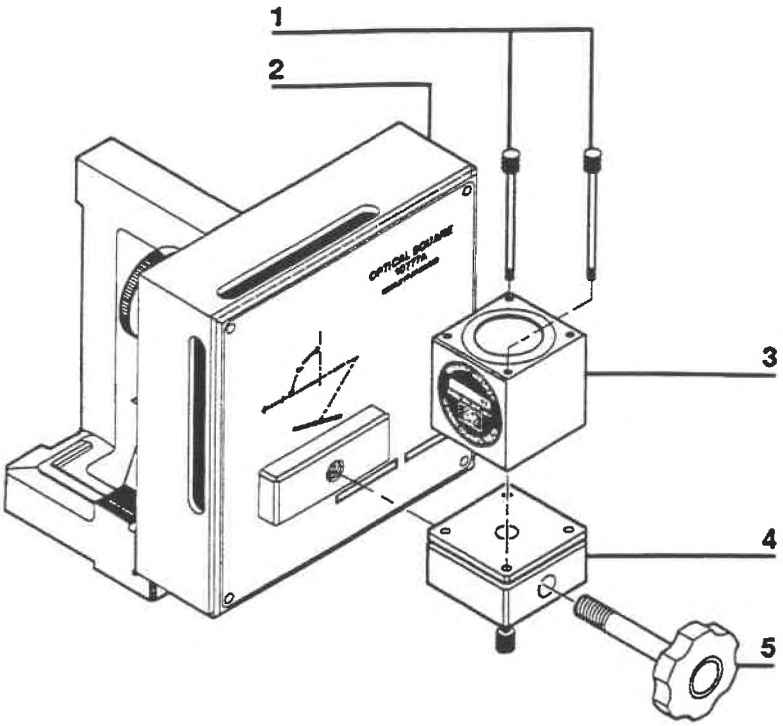
Mounting and aligning optics for the second axis measurement

This section explains how to mount and align the optics for the second axis measurement.

Mounting the optics

To mount the optics for the second axis measurement, follow these steps:

1. **Move the moveable part of the machine to its start position.**
2. **Remove the current interferometer assembly from the spindle and disassemble the assembly.**
3. **Attach the turning mirror base to the optical square using the turning mirror attachment screw (Figure 7–7).**



1 Turning mirror attachment screws
2 Optical square
3 Turning mirror
4 Turning mirror base
5 Turning mirror base attachment screw

Figure 7–7. Assembling and attaching the turning mirror

4 **Orient the turning mirror so that one opening faces the laser head and one opening faces up (Figure 7–8). Then, using the turning mirror attachment screws, attach the turning mirror to its base.**

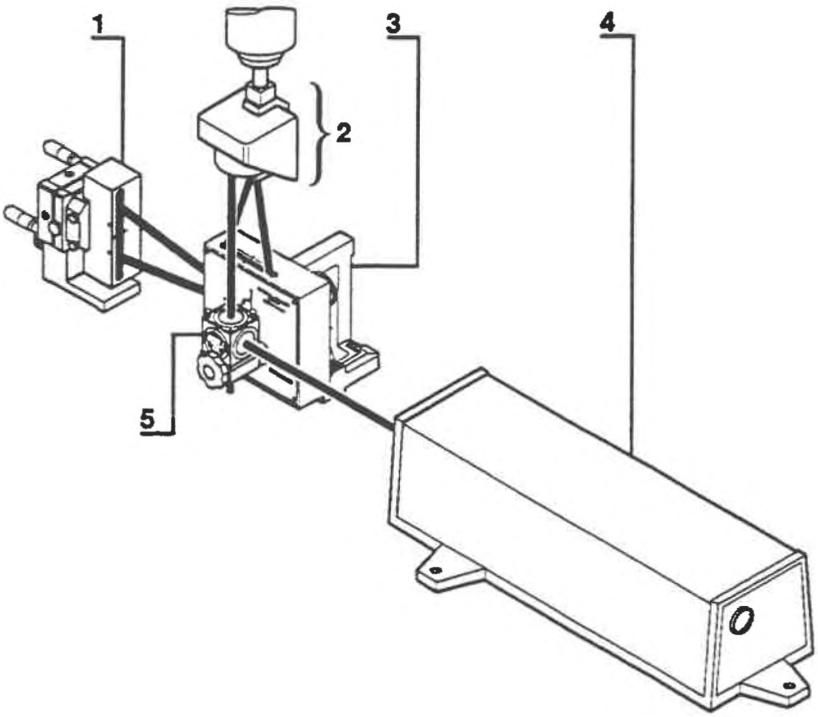

1 Retroreflector oriented vertically
2 Interferometer assembly mounted in a spindle
3 Optical square oriented vertically
4 Laser head
5 Turing mirror
1
2
3
4
5

Figure 7–8. Second axis positioning of optics

5 **Place the optical square vertically on the machine near the reflector (Figure 7–8).**

Make sure that one of the optical square's slots points toward the laser head and the other slot points up.

6 **If your machine has T slots that run along the machine's travel path, place the optical square so its side is parallel to one of the T slots.**

To do this, place two base plates (p/n 10782A) against the edge of a slot and butt the optical square's mount against the base plates. This ensures that the optical square is parallel to the machine's travel path.

7 **Attach the interferometer to the retroreflector (Figure 5–13) using the two screws provided. Then, mount the assembly in the spindle.**

In the rest of this chapter, this assembly made up of the interferometer and the retroreflector is referred to as the "interferometer assembly."

Note Perform steps 8 through 10 as accurately as possible. They are critical for proper alignment of the optics.

8 **Position the interferometer assembly above the optical square as shown in Figure 7–8 so that**

- the interferometer is directly above the turning mirror
- the exposed portion of the retroreflector window is directly above the turning mirror

9 **Move the interferometer assembly close to the optical square. Then align the center of the interferometer's window with the midpoint notches on the optical square.**

10 **Ensure that**

- the top opening in the turning mirror points straight to the interferometer and is not tilted to either side
- the top side of the turning mirror is parallel to the top of the optical square

If necessary, adjust the tilt of the turning mirror with the two screws in the bottom of its base (Figure 5–14).

You are now ready to align the optics.

Aligning the optics

To align the optics, follow these steps:

1 **Set the laser head's upper port to the small aperture by turning the upper aperture control (Figure 2–13).**

2 **Set the turret ring to STRAIGHT.**

3 **Visually align the laser head so it is parallel to the machine's table. Position it so that the beam strikes the center of the turning mirror's opening.**

4 **Translate the laser head horizontally so that its beam enters the threaded hole on the side of the optical square facing the laser head.**

5 **Place a gauge block over the threaded hole and secure it in place using a rubber band (Figure 7-9).**

Make sure the rubber band does not cover the area of the gauge block where the laser beam strikes.

The gauge block reflects the beam back to the laser head. The beam appears as a dot on the face of the laser head. If you cannot see the beam, hold a piece of paper in front of the laser head.

1 Optical square
2 Interferometer assembly
3 Gauge block
4 Laser Head

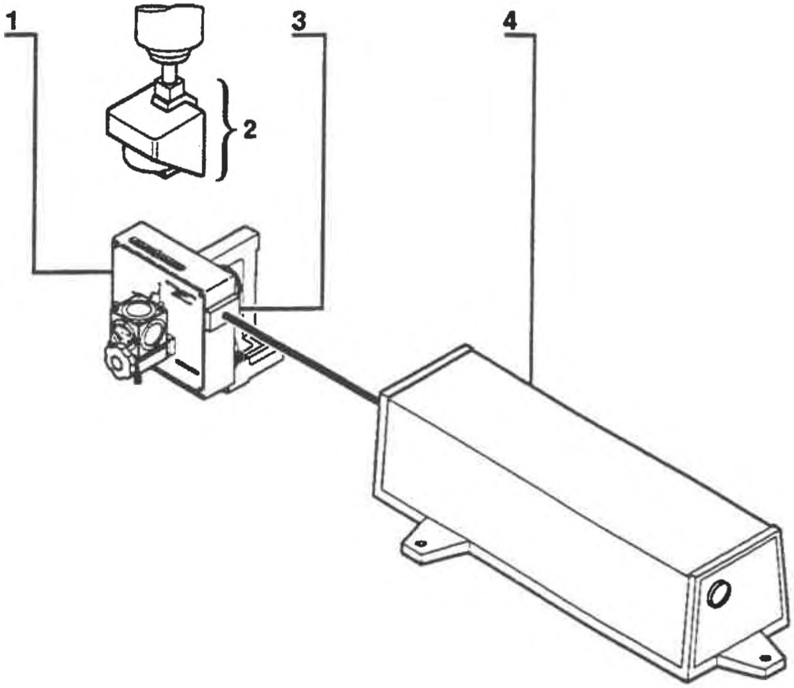


Figure 7–9. Gauge block attached to the side of the optical square

6 **Turn the optical square left and right until the dot enters the upper port on the laser head.**

This makes the optical square perpendicular to the laser beam.

7 **If you cannot get the dot to enter the upper port on the laser head, follow these steps:**

a Remove the interferometer assembly from the spindle.

b Mount a dial indicator in the spindle.

c While moving the table back and forth along the horizontal axis, sweep the side of the optical square.

d Turn the optical square left or right until it is parallel to the direction of travel.

e Return the table to its start position.

f Remove the indicator and remount the interferometer in the spindle.

g Repeat steps 6 through 8 in the previous section, "Mounting the optics."

8 Remove the gauge block.

9 Secure the optical square to the machine using a clamp or similar device.

When using a clamp to secure the optical square, cover as much of its base as possible with the clamp so the attachment is secure.

10 Gently tap the reflector assembly to ensure that its mounting is rigid and free of vibration.

If you feel any vibration, tighten all connections in the mounting.

11 Translate the laser head horizontally until the beam strikes the center of the turning mirror.

If you cannot see the beam, hold a piece of paper in front of the turning mirror.

Your goal in steps 12 through 16 is to make the beam from the turning mirror pass through the alignment ring on the retroreflector, through the interferometer, and through the center of the optical square's top slot.

12 Using the adjusting screws on the turning mirror's base (Figure 5–14), orient the mirror so that the beam passes through the alignment ring on the retroreflector (Figure 5-15).

13 Remove the interferometer from the retroreflector.

14 Place the gauge block over the center of the slot on the top of the optical square (Figure 7–10).

The gauge block reflects the beam back to the laser head. The beam appears as a dot on the face of the laser head.

1 Interferometer assembly
2 Gauge block
3 Laser head
4 Optical square
5 Turning mirror

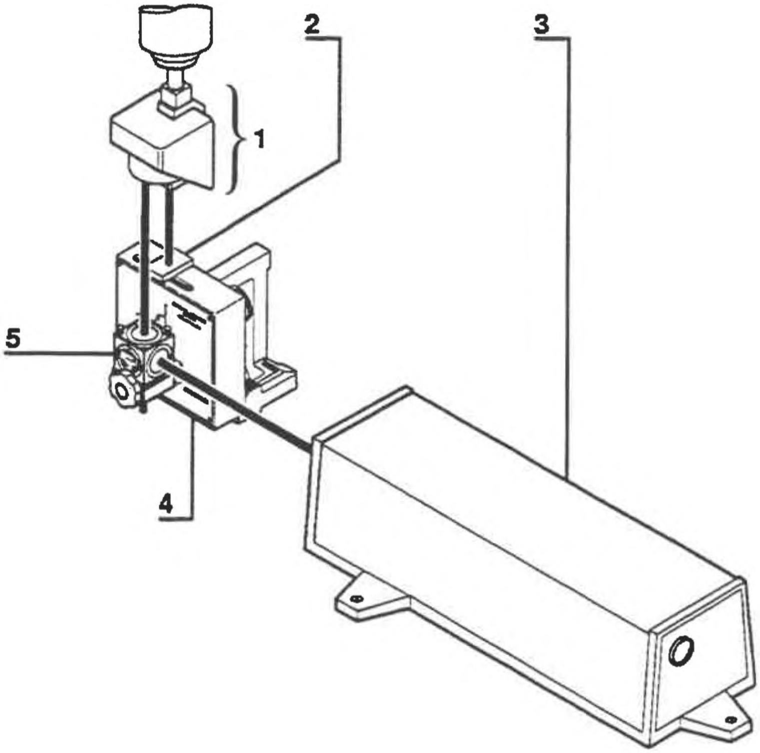


Figure 7–10. Gauge block attached to the top of the optical square

15 Using the adjusting screws on the turning mirror's base (Figure 5–14), orient the mirror so that the reflected beam enters the upper port on the laser head.

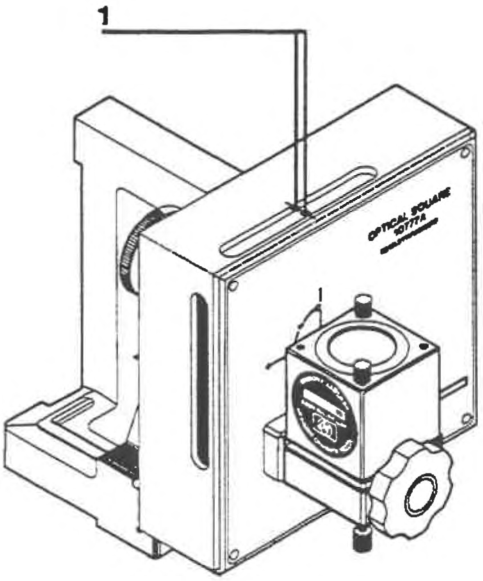
16 If you cannot get the return beam to enter the upper port, follow these steps:

a Remove the gauge block.

b Attach the interferometer to the retroreflector.

c Rotate the interferometer's bezel (Figure 5–9) so the scribe line is perpendicular to the optical square's slot.

d Translate the laser head horizontally and vertically until the two dots are centered between the midpoint notches on the optical square's slot (Figure 7–11).



1 Two dots

Figure 7–11. Initial position of the dots on the optical square

17 **If you cannot get the return beam to enter the upper port using step 16, follow these steps:**

a Repeat steps 8 through 10 in the last section, "Mounting the optics."

b Repeat steps 1 through 15 in this section.

When the beam enters the upper port of the laser head, you are ready to align the laser beam to the machine's travel path.

Aligning the laser beam to the machine's travel path for the second axis measurement

Before using the following instructions, make sure that the turret ring on the laser head is set to STRAIGHT and the large opening is in place over the upper aperture.

To align the laser beam to the machine's travel path, follow these steps:

1 **While watching the two dots on the optical square's surface, move the interferometer away from its start position.**

As you move the optic, the two dots in the optical square's slot separate (Figure 7–12). Your goal is to make sure that (1) they remain in the plane of the midpoint notches on the optical square and (2) both dots remain at an equal distance from the center of the slot.

- If the two dots on the optical square's surface begin to move out of this pattern, tilt the laser head vertically or rotate it left and right to adjust the dots to their correct position.

- If the beam from the turning mirror moves out of the alignment ring on the retroreflector, translate the laser head vertically or horizontally until the beam reenters the ring.

1 Two dots

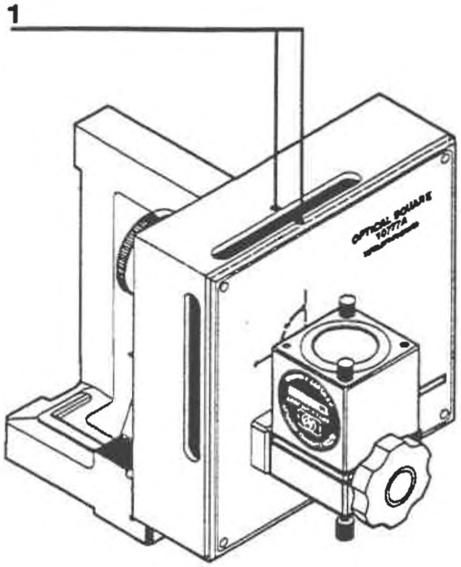


Figure 7–12. Position of the dots on the optical square after moving the interferometer

2 **Repeat step 1 until the machine reaches the end of the travel path.**

You are now ready to check the alignment for beam strength.

Checking the alignment for beam strength for the second axis measurement

Follow the instructions in “Checking the alignment for beam strength” in Chapter 5.

You are now ready to make the second axis measurement.

Making the second axis measurement

To make the second axis measurement, follow these steps:

1 **On the Set Up Laser: Squareness screen, select the second axis you are measuring.**

2 **Repeats steps 3 through 10 in "Making the first axis measurement."**

After you record the last measurement, the Analyze Data: Squareness screen is displayed (Figure 7–6).

3 **Select Save Data to create or update a data file with the measurement data.**

Refer to the *HP 5529A Getting Started Guide* and online help for more information about using the Analyze Data: Squareness screen. Otherwise, you are finished making the measurement.

8. Parallelism measurements

8. Parallelism measurements

8

Parallelism measurements

Parallelism measurements

This chapter explains how to make two types of parallelism measurements: coplanar and spindle. Coplanar parallelism measurements determine if two machine axes move parallel to each other. Spindle parallelism measurements determine if a machine's spindle (on a lathe, for example) is parallel to the travel path of the machine's tool.

Before performing the procedures described in this chapter, you must fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*. For operating specifications for straightness measurement optics, see Appendix A.

1 Optical square, p/n 10777A

……

Straightness accessory kit, p/n 10776A

2 Reflector mount, p/n 10776-67002

3 Straightness retroreflector, p/n 10776-67001

4 Reflector base and posts, p/n 10776-67008

……

Long-range optics kit, p/n 10775A

5 Long-range reflector

6 Long-range interferometer

……

Short-range optics kit, p/n 10774A

7 Short-range reflector

8 Short-range interferometer

……

9 Height adjuster and post, p/n 10785A

……

Turning mirror kit, p/n 10772A

10 Turning mirror

11 Turning mirror base

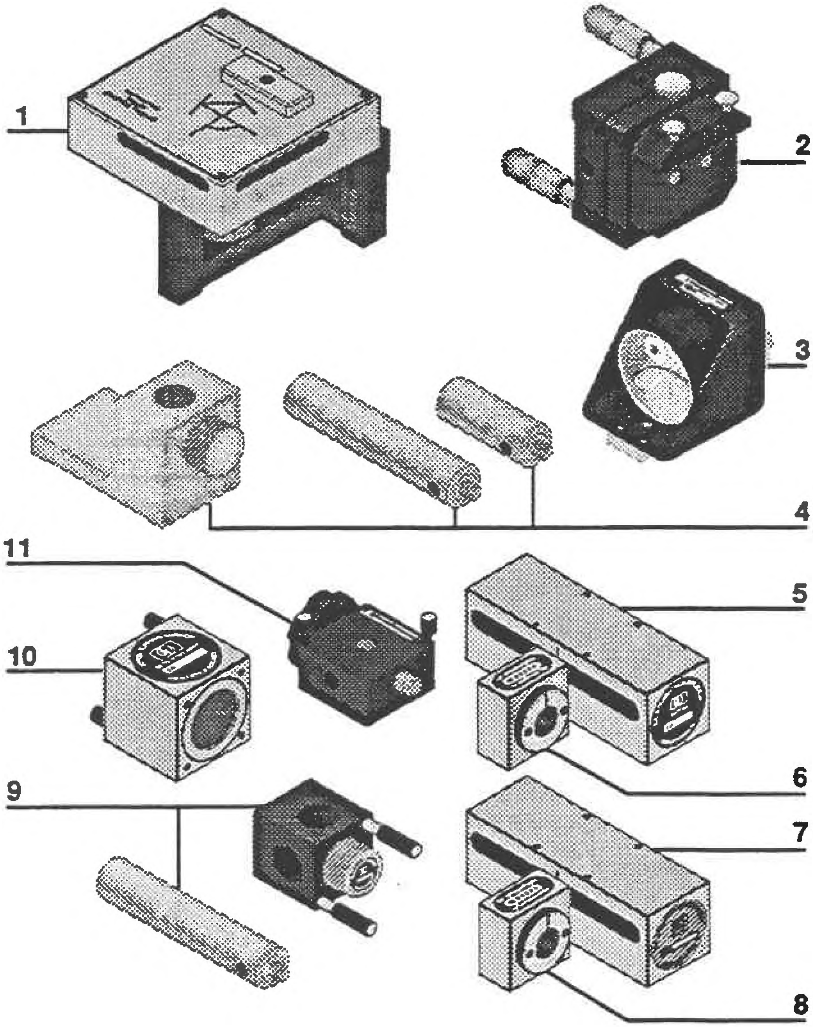


Figure 8–1. Required hardware for parallelism measurements

Setting up for the measurement

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter to make a parallelism measurement. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head, remote control unit, and sensors (if used) to the connectors on the 10886A and 10887A boards installed in the computer.**

The connectors are either on the rear or the side of the computer.

3 **Plug in and turn on all equipment.**

4 **Start the metrology software.**

The Metrology Main Menu is displayed.

5 **On the Metrology Main Menu, select Other Meas.**

The Other Measurements screen is displayed (Figure 8–2).

Alternately, you can open an existing parallelism setup file by selecting Recall Data on the Main Menu.

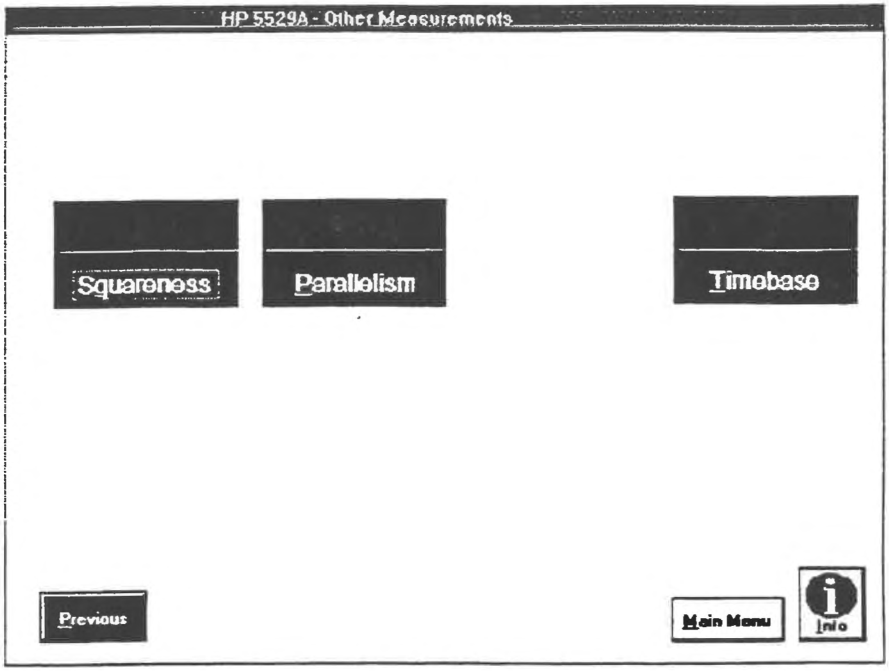
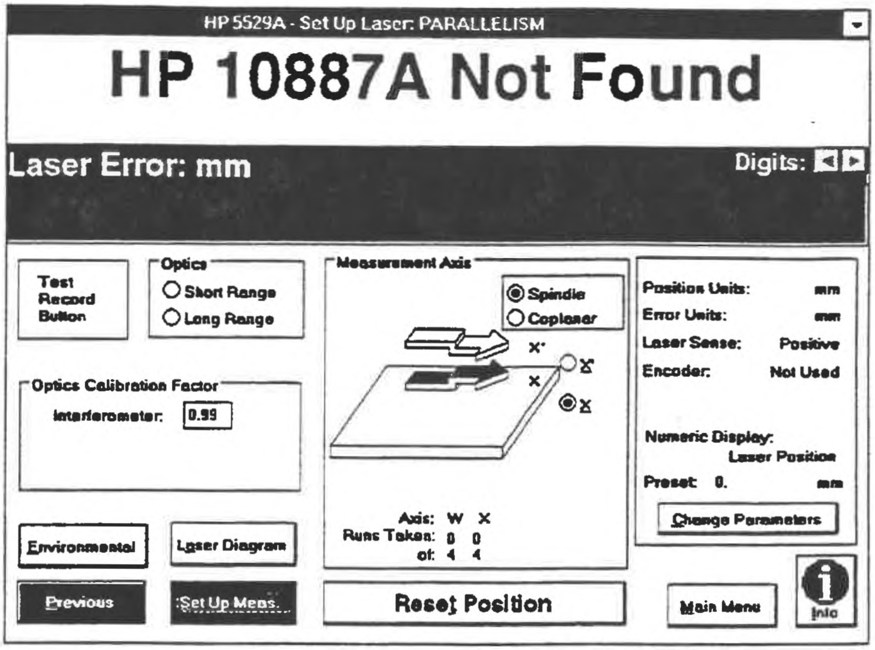

HP 5529A - Other Measurements
Squareness
Parallelism
Timebase
Previous
Main Menu
Info

Figure 8–2. Other Measurements screen

6 **On the Other Measurements screen, select Parallelism.**

The Set Up Laser: Parallelism screen is displayed (Figure 8–3).

You are now ready to position the laser head and target machine.



HP 5529A - Set Up Laser: PARALLELISM

HP 10887A Not Found

Laser Error: mm

Optics: ○ Short Range ○ Long Range

Optics Calibration Factor
Interferometer: 0.99

Measurement Axis: ● Spindle ○ Coplanar

Axis: W X
Runs Taken: 0 0
of: 4 4

Position Units: mm
Error Units: mm
Laser Sense: Positive
Encoder: Not Used

Numeric Display: Laser Position
Preset: 0. mm

Figure 8–3. Set Up Laser: Parallelism screen

Positioning the laser head and target machine

Coplanar parallelism measurements consist of two straightness measurements along each axis of the machine. In the first axis measurement, the software automatically calculates and removes the slope of the first axis (giving the first axis zero slope). The software then removes the same amount of slope from the second axis measurement. Any slope remaining in the second axis is the amount by which the two axes are out of parallelism.

Spindle parallelism measurements also consist of two measurements; however, both measurements are along the same axis. In one measurement, the optics are oriented to determine how much the spindle is out of vertical alignment with the tool travel path. In the second measurement, the optics are aligned to determine how much the spindle is out of horizontal alignment with the tool travel path. The combination of the two out-of-alignment values is the total out-of-parallelism value.

Before you begin to assemble and mount optics for either type of parallelism measurement, you must position the laser head and move the moveable part of the target machine to its start position. Follow these steps:

Note This chapter uses a milling-type machine with a spindle as an example for making coplanar parallelism measurements and a lathe as an example for making spindle parallelism measurements. Although your machine may be different, the general procedures described here still apply.

1. **Position the laser head along the axis most suitable for the measurement you want to make (figure 8–4 or 8–5).**

2. **Move the moveable part of the machine to its start position.**

3. **Adjust the laser head to the approximate height at which you will mount the optics.**

4. **Determine how to position the optics. See figure 8–4 , 8–5 and 8–6 for illustrations of optics setups, and use the following guidelines:**

   - Mount the interferometer or the combined retroreflector/interferometer assembly where the tool mounts.

   - Mount the reflector where the workpiece mounts.

A Measurement in a horizontal plane along the Z-axis

B Measurement in a vertical plane along the Z-axis

••••••••••••••••••••••••••

1 Interferometer assembly oriented horizontally in a spindle

2 Interferometer assembly oriented vertically in a spindle

3 Reflector oriented vertically

4 Laser head

5 Reflector oriented horizontally

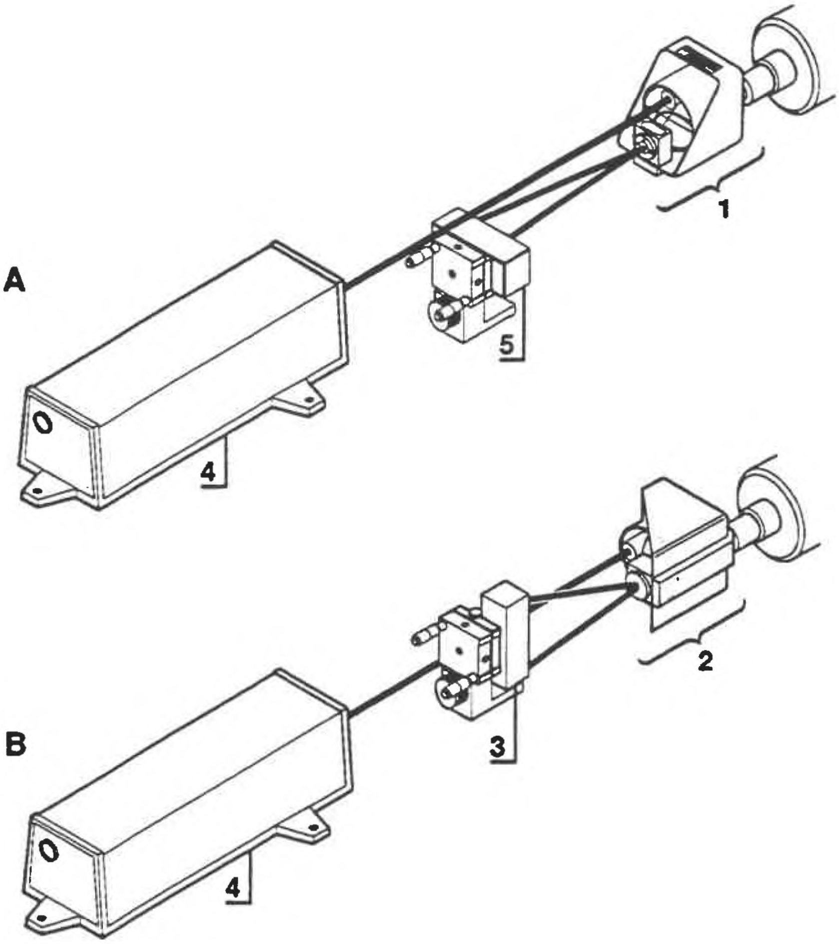


Figure 8–4. Positioning of optics for coplanar parallelism measurements

1 Reflector mounted horizontally

2 Interferometer mounted where tool mounts

3 Turning mirror

4 Laser head placed perpendicular to spindle

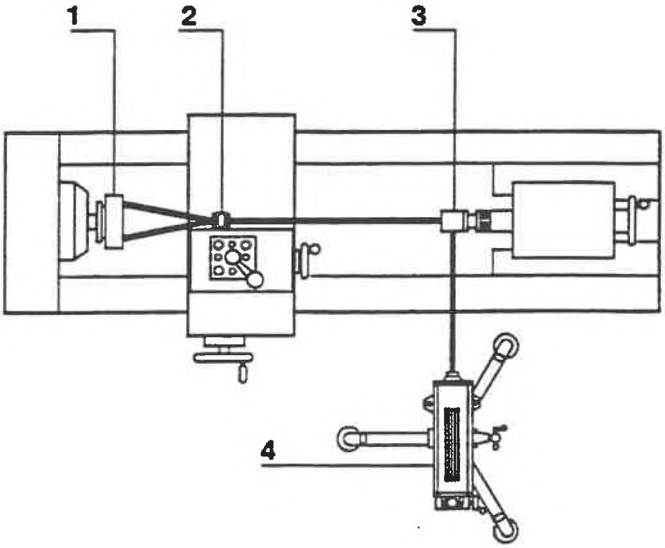
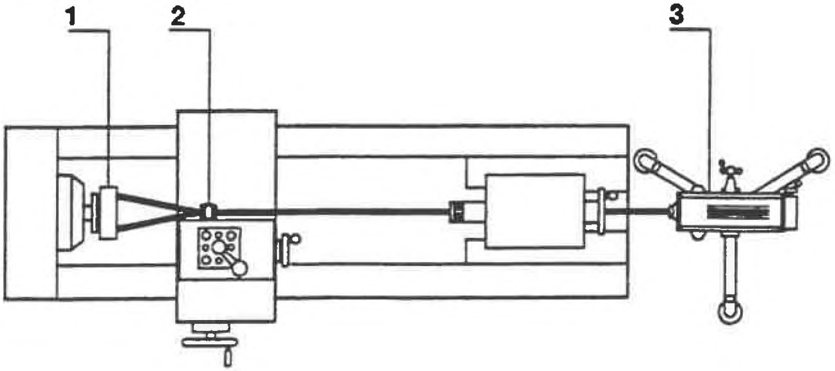


Figure 8–5. Positioning of optics for spindle parallelism measurements—solid or heavy tailstock, or no tailstock



1 Reflector mounted horizontally

2 Interferometer mounted where tool mounts

3 Laser head placed parallel to spindle, behind tailstock

Figure 8–6. Positioning of optics for spindle parallelism measurements—hollow tailstock

You are now ready to assemble, mount, and align the optics. To make a spindle parallelism measurement, go directly to "Mounting and aligning optics for spindle parallelism measurements" later in this chapter. To make a coplanar parallelism measurement, continue with the next section, "Mounting and aligning optics for coplanar parallelism measurements."

Mounting and aligning optics for coplanar parallelism measurements

Depending on the two axes you want to compare for parallelism and the type of target machine, follow the instructions in one of the following sections in Chapter 5, "Straightness measurements":

- "Mounting and aligning optics for X-axis or Y-axis measurements"
- "Mounting and aligning optics for vertical Z-axis measurements"
- "Making vertical axis straightness measurements"

After you mount and align the optics, you are ready to align the laser beam to the machine's travel path. Go directly to "Aligning the laser beam to the machine's travel path" later in this chapter.

Mounting and aligning optics for spindle parallelism measurements

This section explains how to assemble, mount, and align the optics necessary for a spindle parallelism first axis measurement.

Mounting the optics

To mount the optics for spindle parallelism measurements, follow these steps:

1 **Place the laser head along the most suitable axis according to the following guidelines:**

- If the tailstock is not hollow or is too heavy, place the laser head at the end of the tool's travel path so the laser head is perpendicular to the spindle (Figure 8–5).

- If the tailstock is hollow, place the laser head behind it, parallel to the spindle (Figure 8–6). With this configuration, you direct the laser beam through the tailstock.

- If the tailstock is light, remove it. Then place the laser head at the end of the lathe, parallel to the spindle (Figure 8–6).

CAUTION If the tailstock is heavy enough so that one end of the lathe rises even a small distance after you take it off, your measurement will not be accurate. Therefore, do not remove the tailstock if you think removing it would cause the end of the machine to rise.

- If your lathe does not have a tailstock, place the laser head at the end of the lathe so it is parallel to the spindle (Figure 8–6).

2 **Adjust the laser head to the approximate height at which you will mount the optics.**

3 **Attach the reflector to the reflector mount using the two attachment screws on the top of the reflector mount (Figure 5–8.)**

Position the reflector so the slot is closest to the top edge.

4 **Screw the reflector mounting post into the *back* of the reflector mount.**

Throughout the rest of this chapter, this unit is referred to as the "reflector assembly."

5 **Mount the reflector assembly horizontally or vertically in the spindle (figure 8–5 or 8–6).**

Although Figure 8–5 shows the reflector mounted horizontally, you may mount it horizontally or vertically.

6 **Mount the interferometer on the tool post so the beam passes through it (figure 8–5 or 8–6).**

The mounting hardware that you use depends on the type of machine you are calibrating.

7 **If you did not remove the tailstock, attach the turning mirror to its base and mount it on the tailstock. Follow these steps:**

a Remove the large knob from the turning mirror's base and screw in a post.

b Mount the post in the tailstock so the turning mirror's base is oriented horizontally.

c Place the turning mirror on the turning mirror base so that one opening faces the laser head and one opening faces the spindle.

d Attach the turning mirror to its base using the two attachment screws.

You are now ready to align the optics.

Aligning the optics

To align the optics, follow these steps:

1 **If you are using a turning mirror, follow these steps (otherwise, go directly to step 2):**

a Ensure that the side of the turning mirror facing the laser head is not tilted up or down.

b Adjust the laser head's position so that the beam is perpendicular to the turning mirror and strikes the center of the turning mirror.

2 **Remove the interferometer from the interferometer assembly.**

3 **Adjust the laser head so that the beam is centered between the midpoint notches on the reflector.**

If you are using a turning mirror, you can also center the beam by adjusting the turning mirror's tilt.

4 **Reattach the interferometer to the interferometer assembly.**

You are now ready to align the laser beam to the machine's travel path.

Aligning the laser beam to the machine's travel path

If you are making a coplanar parallelism measurement, you must align the laser beam to the travel path of one axis only. It is best to align the laser beam to the longer of the two axes.

If you are making a spindle parallelism measurement, you must align the laser beam to the axis of the tool's travel path only.

To align the laser beam to the machine's travel path, follow the instructions in "Aligning the laser beam to the machine's travel path" in Chapter 5. (Although Chapter 5 refers to straightness software screens instead of parallelism screens, the instructions still apply).

You are now ready to check the alignment for beam strength.

Checking the alignment for beam strength

If you are making a coplanar parallelism measurement, you must check for beam strength along both measurement axes. You can check either axis first.

If you are making a spindle parallelism measurement, you must check for beam strength along the axis of the tool's travel path only.

To align the laser beam to the machine's travel path, follow the instructions in "Aligning the laser beam to the machine's travel path" in Chapter 5. (Although Chapter 5 refers to straightness software screens instead of parallelism screens, the instructions still apply).

You are now ready to make parallelism measurements. To make coplanar parallelism measurements, go directly to "Making coplanar parallelism measurements." To make spindle parallelism measurements, continue with "Making spindle parallelism measurements."

Making spindle parallelism measurements

In spindle parallelism measurements, you make four sets of measurements with the reflector oriented as follows:

1. In the first set, the reflector is oriented either horizontally or vertically.
2. In the second set, the reflector is rotated 180 degrees relative to the first set.
3. In the third set, the reflector is rotated 90 degrees relative to the second set.
4. In the fourth set, the reflector is rotated 180 degrees relative to the third set.

It does not matter whether you begin with the horizontal or vertical measurements.

You make manual measurements as you advance the machine's moveable part. The instructions explain how to make measurements using either the Record button displayed on the screen or the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

Making the first set of measurements

To make the first set of measurements, follow these steps:

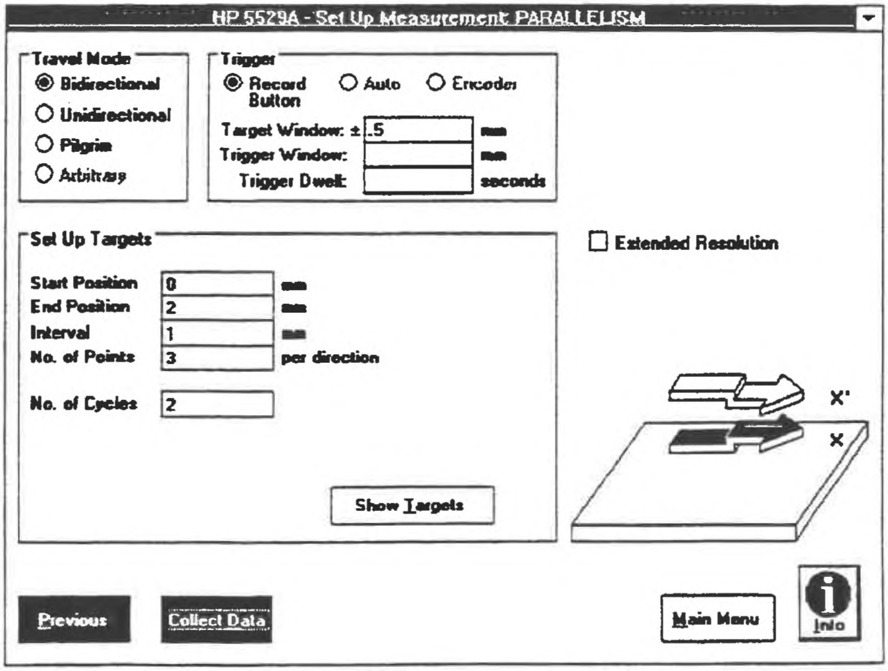
1. **On the Set Up Laser: Parallelism screen, do the following:**
   - In the Measurement Axis box, select Spindle.

- In the Measurement Axis box, select X.

For instructions on completing the other fields on the screen, use the online help.

2 Select Set Up Meas.

The Set Up Measurement: Parallelism screen is displayed (Figure 8-7).



HP 5529A - Set Up Measurement: PARALLELISM

Travel Mode
● Bidirectional
○ Unidirectional
○ Pilgrim
○ Arbitrary

Trigger
● Record Button ○ Auto ○ Encoder
Target Window: ± .5 mm
Trigger Window: mm
Trigger Dwell: seconds

☐ Extended Resolution

Set Up Targets
Start Position 0 mm
End Position 2 mm
Interval 1 mm
No. of Points 3 per direction
No. of Cycles 2

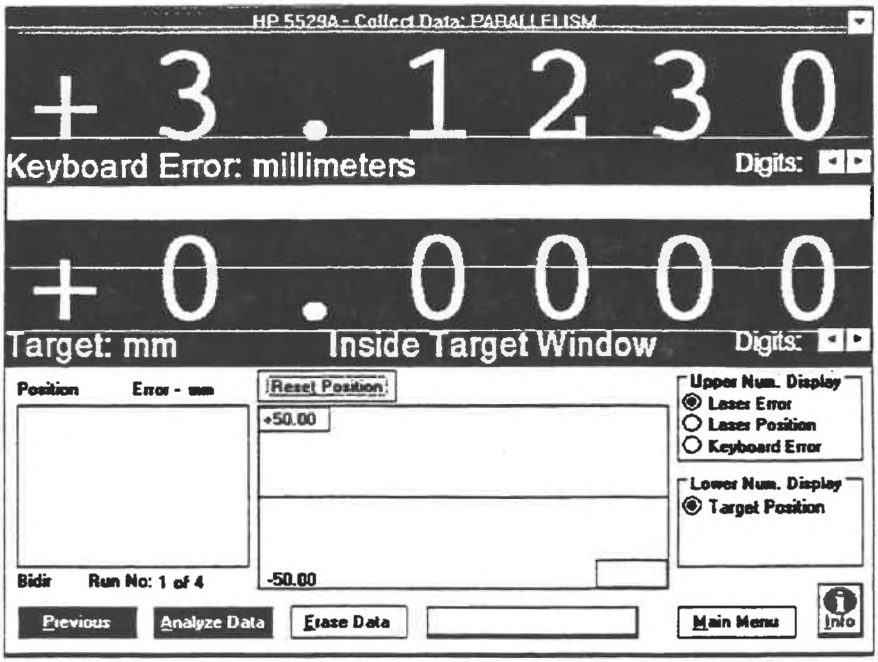
Figure 8–7. Set Up Measurement: Parallelism screen

3 Complete the fields on the Set Up Measurement: Parallelism screen.

If necessary, use the online help.

4 Select Collect Data.

The Collect Data: Parallelism screen is displayed (Figure 8–8).



HP 5529A - Collect Data: PARALLELISM

+3.1230

Keyboard Error: millimeters

+0.0000

Target: mm Inside Target Window

Upper Num. Display: ● Laser Error ○ Laser Position ○ Keyboard Error

Lower Num. Display: ● Target Position

Bidir Run No: 1 of 4

Digits:
Position
Error - mm
Reset Position
+50.00
-50.00
Previous
Analyze Data
Erase Data
Main Menu
Info

Figure 8–8. Collect Data: Parallelism screen

5 **On the Collect Data: Parallelism screen, select Reset Position.**

This tells the system that the current position of the reflector is the “zero” point, from which all distances will be measured.

If necessary, use the online help to complete the rest of the fields on this screen.

6 **Move the machine’s moveable part to the first measurement point.**

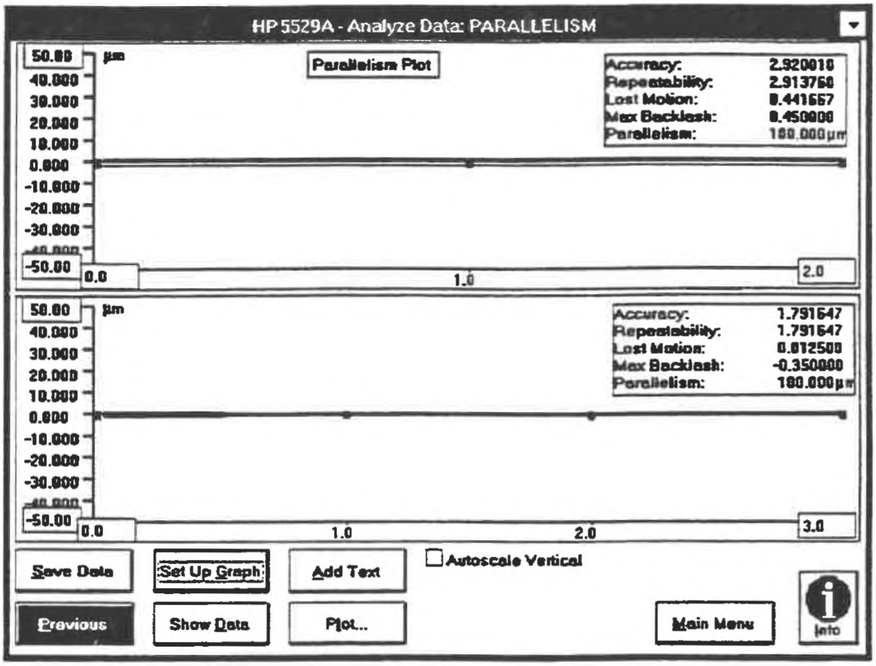
7 **Select Record.**

If you are using the optional remote control unit, press the Record button.

8 **Continue moving the machine’s moveable part to each point and recording measurements until you are finished.**

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. Select Reset Position to reset the system.

After you record the last measurement, the Analyze Data: Parallelism screen is displayed (Figure 8–9).


HP 5529A - Analyze Data: PARALLELISM

Accuracy: 2.920010
Repeatability: 2.913760
Lost Motion: 0.441667
Max Backlash: 0.450000
Parallelism: 100.000µm

Accuracy: 1.791647
Repeatability: 1.791647
Lost Motion: 0.012500
Max Backlash: -0.350000
Parallelism: 100.000µm

☐ Autoscale Vertical

Parallelism Plot
50.00
µm
40.000
30.000
20.000
10.000
0.000
-10.000
-20.000
-30.000
-40.000
-50.00
0.0
1.0
2.0
50.00
µm
40.000
30.000
20.000
10.000
0.000
-10.000
-20.000
-30.000
-40.000
-50.00
0.0
1.0
2.0
3.0
Save Data
Set Up Graph
Add Text
Previous
Show Data
Plot...
Main Menu
Info

Figure 8–9. Analyze Data: Parallelism screen

9 **On the Analyze Data: Parallelism screen, select Next Axis.**

You are returned to the Set Up Laser: Parallelism screen.

You are now ready to make the second set of measurements.

Making the second set of measurements

To make the second set of measurements, follow these steps:

1 **Rotate the reflector 180 degrees.**

2 **Select X' on the Set Up Laser: Parallelism screen.**

3 **Repeat steps 2 through 8 in "Making the first set of measurements."**

A pop-up window is displayed. The parallelism measurement value is displayed in the Parallelism field.

4 **Write down the number displayed in the Parallelism field.**

5 **Select Previous.**

You are now ready to make the third set of measurements.

Making the third set of measurements

To make the third set of measurements, follow these steps:

1 **Rotate the reflector 90 degrees.**

2 **On the Analyze Data: Parallelism screen, select Main Menu.**

The Metrology Main Menu is displayed.

3 **On the Metrology Main Menu, select Parallelism.**

The Set Up Laser: Parallelism screen is displayed (Figure 8–3).

4 **Repeat steps 1 through 9 in "Making the first set of measurements."**

5 **On the Analyze Data: Parallelism screen, select Next Axis.**

You are now ready to make the fourth set of measurements.

Making the fourth set of measurements

To make the fourth set of measurements, repeat the steps in "Making the second set of measurements." After you make the fourth set of measurements, the Analyze Data: Parallelism screen is displayed.

You are now ready to calculate the total out-of-parallelism value.

Calculating the total out-of-parallelism value

To calculate the total out of parallelism value, follow these steps:

1 **Square the parallelism value that you obtained from the first set of measurements.**

2 **Square the parallelism value that you obtained from the second set of measurements.**

3 **Add the two figures together.**

4 **Calculate the square root of the sum.**

5 **On the Analyze Data: Parallelism screen, Select Save Data to create or update a data file with the measurement data.**

Refer to the *HP 5529A Getting Started Guide* and online help for more information about using the Analyze Data: Parallelism screen. Otherwise you are finished making the measurement.

Making coplanar parallelism measurements

In coplanar parallelism measurements, you can measure either axis first. You make manual measurements as you advance the machine's moveable part. The instructions explain how to make measurements using either the Record button displayed on the screen or the optional remote control unit. See Chapter 1, "Planning your measurement," for a description of other triggering methods.

Making the first axis measurement

To make the first axis measurement, follow these steps:

1 **Return each of the two moveable parts to its start position.**

2 **On the Set Up Laser: Parallelism screen, do the following:**

- In the Measurement Axis box, select Coplanar.
- In the Measurement Axis box, select X.

  "X" tells the system this is the first axis measurement.

For instructions on completing the other fields on the screen, use the online help.

3 **On the Set Up Laser: Parallelism screen, select Set Up Meas.**

The Set Up Measurement: Parallelism screen is displayed (Figure 8-6).

4 **Complete the fields on the Set Up Measurement: Parallelism screen.**

If necessary, use the online help.

5 **Select Collect Data.**

The Collect Data: Parallelism screen is displayed (Figure 8–8).

6 **On the Collect Data: Parallelism screen, select Reset Position.**

This tells the system that the current position of the reflector is the "zero" point, from which all distances will be measured.

For instructions on completing the other fields on the screen, use the online help.

7 **Move the machine's moveable part until the machine has reached the first measurement position.**

8 **Select Record.**

If you are using the optional remote control unit, press the Record button.

9 **Continue moving the machine's moveable part to each point and recording measurements until you are finished.**

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. Move the reflector back to the zero position then select Reset Position to reset the system.

After you record the last measurement, the Analyze Data: Parallelism screen is displayed (Figure 8–9).

10 **On the Analyze Data: Parallelism screen, select Next Axis.**

You are returned to the Set Up Laser: Parallelism screen.

You are now ready to make the second axis measurement.

Making the second axis measurement

To make the second axis measurement, follow these steps:

1 **Move the first axis moveable part to its start position.**

2 **On the Set Up Laser: Parallelism screen, do the following:**

- In the Measurement Axis box, select Coplanar.
- In the Measurement Axis box, select W.

  "W" tells the system this is the second axis measurement.

3 **Repeat steps 3 through 8 in the last section, "Making measurements along the first axis."**

Move the second axis moveable part.

A pop-up window is displayed. The parallelism value for the two axes is displayed in the Parallelism field.

4 **Select Save Data to create or update a data file with the measurement data.**

Refer to the *HP 5529A Getting Started Guide* and online help for more information about using the Analyze Data: Parallelism screen. Otherwise, you are finished making the measurement.

9. Flatness measurements

9. Flatness measurements

9

Flatness measurements

Flatness measurements

This chapter explains how to make flatness measurements at multiple points along measurement lines of a grid on a surface plate. You make flatness measurements to check the flatness of a surface plate or similar object. You would do this, for example, to ensure that the object meets flatness specifications or requirements.

Before performing the procedures described in this chapter, you should fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*.

Since you use the angular interferometer and reflector to make flatness measurements, see angular measurement specifications for these optics in Appendix A. See the flatness measurement specifications for flatness specifications.

1 Footspacing kit, p/n 10759A

2 Angular interferometer, p/n 10770A

3 Angular reflector, p/n 10771A

4 Two alignment targets, p/n 10767-67001

5 Two flatness mirrors with base, p/n 10773A

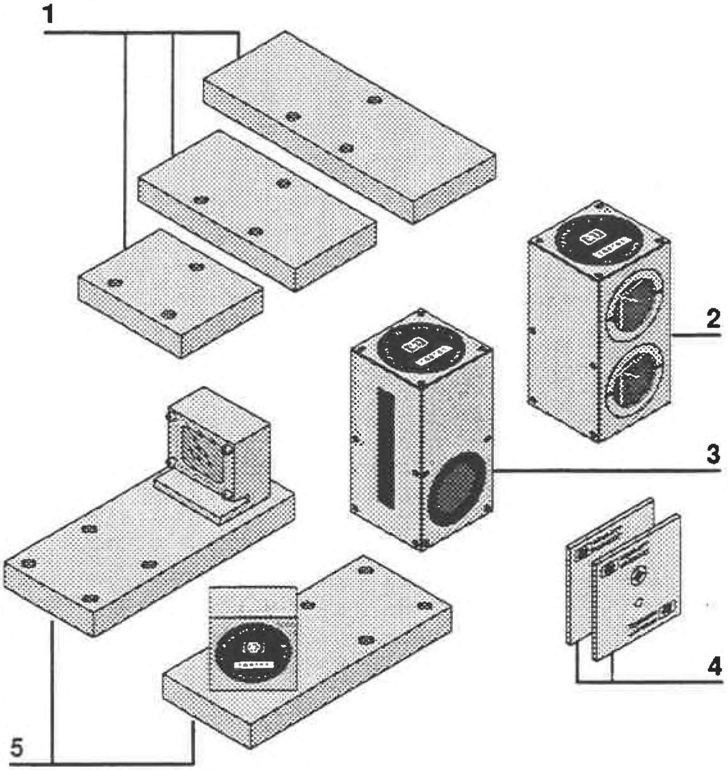


Figure 9–1. Required hardware for flatness measurements

Setting up for the measurement

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter to make a flatness measurement. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head and remote control unit to the appropriate ports in the computer.**

The connectors are either on the rear or on the side of the computer.

Note You do not need to compensate for environmental factors when making flatness measurements. However, if you will make other measurements later and plan to use the sensors, connect them to the appropriate ports now.

3 **Plug in and turn on all equipment.**

4 **Start the metrology software.**

The Metrology Main Menu is displayed.

5 **On the Metrology Main Menu, select Other Meas.**

The Other Measurements screen (Figure 9–2) is displayed.

Alternatively, you can open an existing flatness measurement setup file by selecting Recall Data on the Main Menu, then selecting the file.

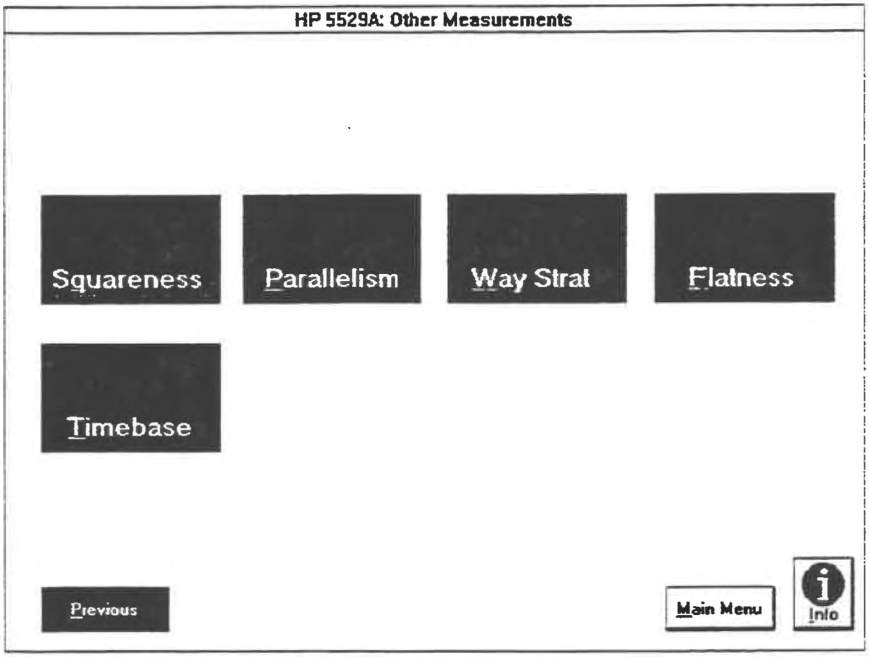

HP 5529A: Other Measurements
Squareness
Parallelism
Way Strat
Flatness
Timebase
Previous
Main Menu
Info

Figure 9–2. Other Measurements screen

The rest of this section explains how to plan your measurement and draw the measurement grid.

Creating the measurement grid

This section gives you information about flatness measurement grids and explains how to draw one.

Planning your measurement grid

To measure the flatness of a surface plate, you must draw the lines along which you will make measurements on the surface plate. The border of the grid is determined by whether or not you can align the laser head with each of the measurement lines by moving the laser head around the surface plate

Usually, the floor area around the surface plate is clear enough to allow you to move the laser head from line to line around the surface plate in order to make measurements.

Sometimes, however, the surface plate is in a corner or has equipment by it that prevents you from moving the laser head around all sides of the surface plate. If this is the case, first measure the axes along which you can align the laser beam. Then, line up the laser head with one side of the surface plate and use flatness mirrors to direct the laser beam along each remaining measurement axis.

Note Measurements using flatness mirrors are more complicated and take longer to perform than measurements without flatness mirrors. Use flatness mirrors only if it is necessary.

After you have determined whether you will use flatness mirrors, you are ready to draw the measurement grid.

Determining grid border requirements

In order to properly position the optics on the surface plate, you must leave a border between the measurement grid perimeter lines and the edge of the surface plate.

If you can move the laser head to each measurement line, leave at least a 51- to 76-mm (2- to 3-inch) border. The border allows sufficient room for you to place optics for measurements along the perimeter lines. Figure 9–3 shows an example of a measurement grid with 76-mm (3-inch) borders.

Choosing a footspacer

Before you draw the measurement lines, choose a footspacer. You use the footspacers to mark the measurement points, called "stations," on the lines as you are drawing the grid. The footspacer kit includes three footspacers: 51-mm (2-inches), 102-mm (4-inches), and 152-mm (6-inches). These sizes are actually the distances between the scribe lines on the leading and trailing feet of the footspacers rather than the overall length of the footspacers.

When choosing a footspacer, remember that the smaller the footspacer, the longer it will take you to perform the entire measurement process, but the better your measurement resolution will be.

1	Surface plate
2	Measurement grid
3	Laser head
4	Nameplate
*	76-mm (3-inch) margin between grid and surface plate

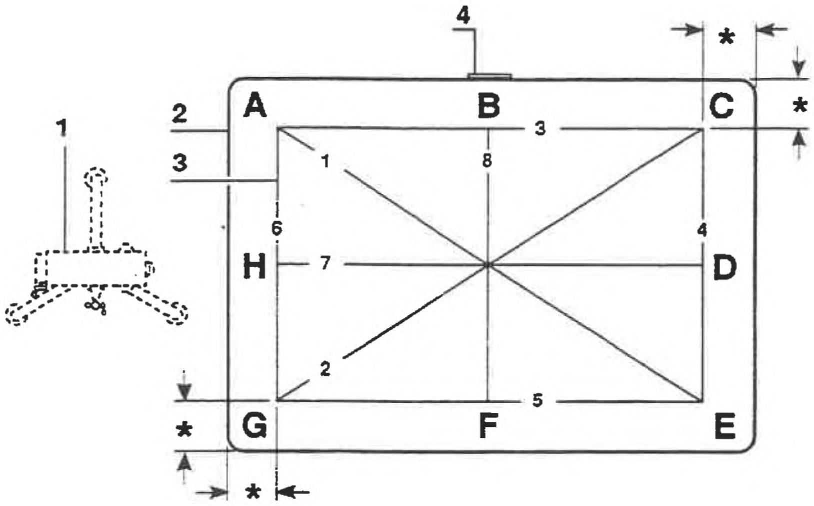


Figure 9–3. Measurement setup when flatness mirrors are not used

If you will use a flatness mirror for one or more lines, leave at least a 102-mm (4-inch) border along one edge. This border allows sufficient room for you to place the flatness mirrors. The other sides require only a 51- to 76-mm (2- to 3-inch) border. Figure 9–4 shows an example of the measurement grid necessary when flatness mirrors are used.

1	Surface plate
2	Measurement grid
3	Laser head
4	Nameplate
*	76-mm (3-inch) margin between grid and edge of surface plate
**	102-mm (4-inch) margin between the grid and edge of the surface plate

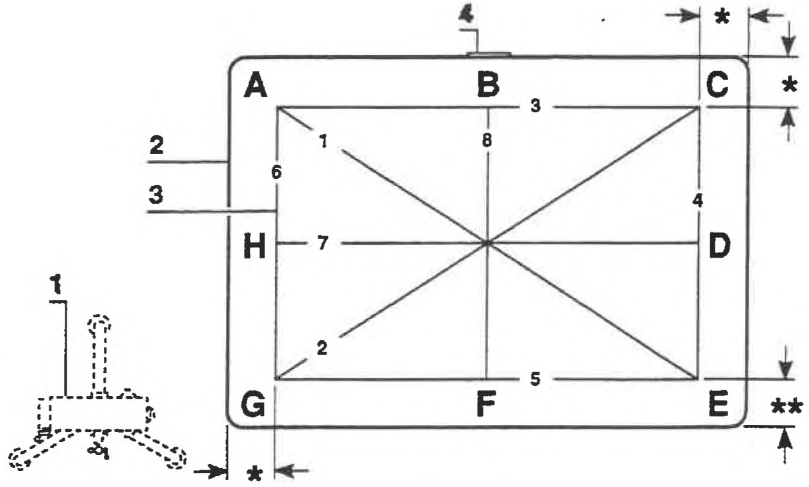


Figure 9–4. Measurement setup when flatness mirrors are used

Figures 9–3 and 9–4 include line numbers and uppercase letters that indicate the end points and the midpoint of each standard line. These numbers and letters are used in this documentation and in the software to refer to the lines on the grid.

Now that you understand the grid border requirements, you are ready to draw the perimeter lines of the measurement grid.

Drawing the perimeter lines of the measurement grid

Although you have already approximated the border for your measurement, in this section you draw the lines that define the actual border for your measurement (lines 3 through 6). To correctly draw the measurement grid, you must first draw the perimeter lines of the measurement grid. To do so, refer to figures 9-3 and 9-4, and follow these steps:

1 **Use the footspacer to mark stations on the straightedge.**

You can then use the straightedge to mark these stations on the surface plate. Remember, the size of the interval is the distance between the scribe lines on the footspacer you chose.

2 **Using a straightedge and a pencil or chalk, draw a perimeter line on the side closest to the surface plate's nameplate (Line 3).**

Be sure to leave the correct size border between the line and the edges of the surface plate.

3 **Mark the footspacer stations on the line by following these steps:**

a Mark the midpoint of Line 3 (Point B).

b Align the center of the straightedge with this midpoint.

c Starting at the midpoint, mark your measurement stations in both directions on the line.

Remember, the size of the intervals is the distance between the scribe lines on the footspacer you chose.

Do not mark within your border. If marking a station extends the line into the border between the measurement grid and the edge of the surface plate, the previous station is now the end of the line (points A and C).

Note the number of stations marked.

d Mark the end points of Line 3.

e Write down the length of the line in millimeters or inches. You enter this length in the Set Up Flatness screen.

The length of the line is the number of stations multiplied by the distance between stations.

4 **Starting at the end (Point C) of the first perimeter line (Line 3), draw a second line perpendicular to the first line (Line 4).**

Be sure to leave the correct size border between the end of the line and the edge of the surface plate.

5 **Mark stations on Line 4 by following these steps:**

   a Starting at the end of the line that connects with Line 3 (Point C), mark your measurement stations along this line. Be sure to mark an even number of stations.

   The last station you mark is now the end of Line 4 (Point E).

   Note the number of stations marked.

   b Mark the midpoint of the line (Point D).

6 **Draw the third perimeter line (Line 6) the same length as and parallel to Line 4.**

This line must be perpendicular to the first line.

7 **Using Line 4 as a guide, mark stations at the same locations on this line.**

Write down the length of the line in millimeters or inches. You enter this length in the Set Up Flatness screen later.

The length of the line is the number of stations multiplied by the distance between stations.

8 **Draw Line 5 by connecting the ends of lines 4 and 6.**

9 **Using Line 3 as a guide, mark stations at the same locations on this line.**

You should have a rectangle with pairs of equal sides and an equal number of stations on opposing sides. If you do not, recheck your work.

You are now ready to draw the internal measurement lines.

Drawing the internal measurement lines.

To draw the internal measurement lines, follow these steps:

1 **Draw diagonal lines to connect opposite corners of the grid (AE and GC in Figure 9–3 or 9–4).**

2 **Mark stations on each of the diagonals, following these guidelines:**

- Mark stations outward from the intersection point of the two diagonals.
- Both halves of a diagonal must have the same number of stations.
- If you cannot mark a whole number of stations on the diagonal, you can either stop short of or continue past the end of the diagonal. The software indicates the number of stations you should mark on the diagonal.
- You must have the same number of stations on each diagonal. If not, all corners of the measurement grid may not be 90 degrees; recheck your work.

3 **Draw lines to connect the midpoints of opposite sides of the grid (lines 7 and 8 in figure 9–3 or 9–4).**

4 **Mark stations on lines 7 and 8.**

The number of stations on lines 7 and 8 must equal the number of stations on the perimeter lines that parallel them. If not, recheck your work.

You are now ready to assemble and mount the optics.

Assembling and mounting the optics

This section explains how to assemble the optics and mount them on the surface plate.

Note The footspacers in the footspacer kit have three feet. One side of each footspacer has two feet, the opposite side has one foot centered between the other two feet. In the rest of this chapter, these two feet are referred to as the "measurement line feet."

Assembling the optics

To assemble the optics, follow these steps:

1 **Using the screws provided, attach the angular reflector to the footspacer you chose (Figure 9–5). Follow these guidelines.**

Attach the reflector to the footspacer so that after you place the reflector and footspacer on the surface plate:

- The side of the reflector with two openings faces the laser beam.
- The measurement line feet are centered over the measurement line (Figure 9–6).

1 Angular reflector

2 Footspacer

3 Attachment screws

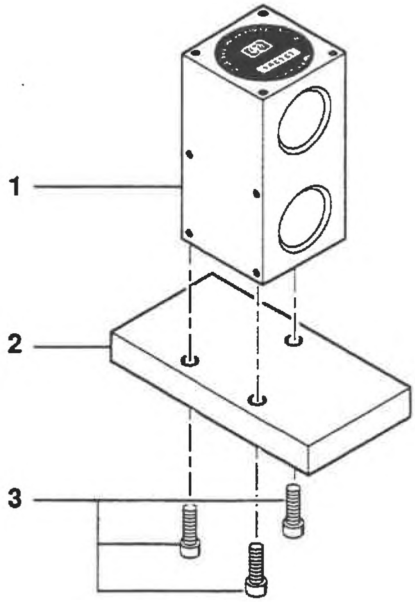


Figure 9–5. Attaching the reflector to a footspacer

1	Footspacer
2	Trailing foot
3	Leading foot
4	Measurement line
5	Station
6	Direction of travel

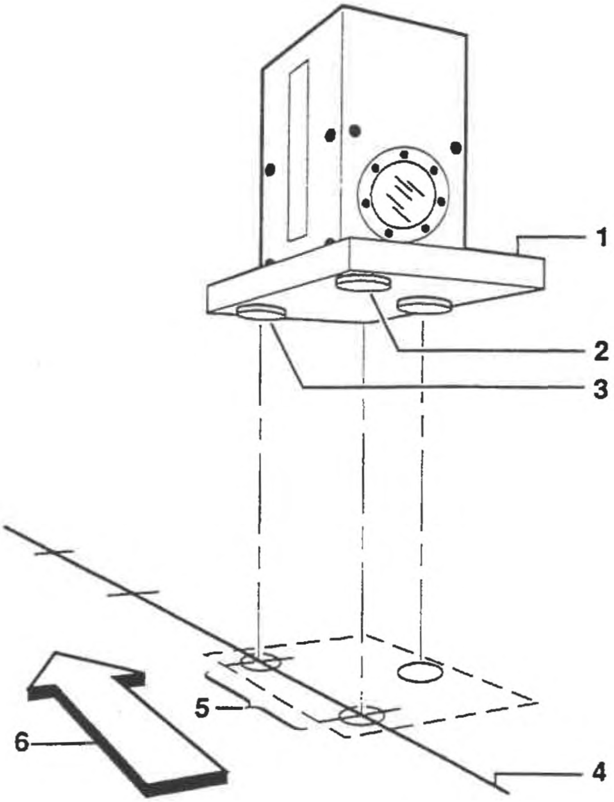


Figure 9–6. Centering the leading and trailing feet over the measurement line

2 **Attach the angular interferometer to a flatness mirror base (Figure 9–7). Follow these guidelines.**

If you are not using flatness mirrors, attach the interferometer so the side of the interferometer with one opening faces the laser head and one of the closed sides faces the flatness mirror.

If you are using flatness mirrors, attach the interferometer so the side of the interferometer with one opening faces the flatness mirror. In the remainder of this chapter, this assembly of the interferometer, flatness mirror, and flatness mirror base is referred to as the "interferometer assembly."

A Attaching the interferometer if using a flatness mirror

B Attaching the interferometer if not using a flatness mirror

****

1 Angular interferometer

2 Turning mirror

3 Turning mirror base

4 Attachment screws

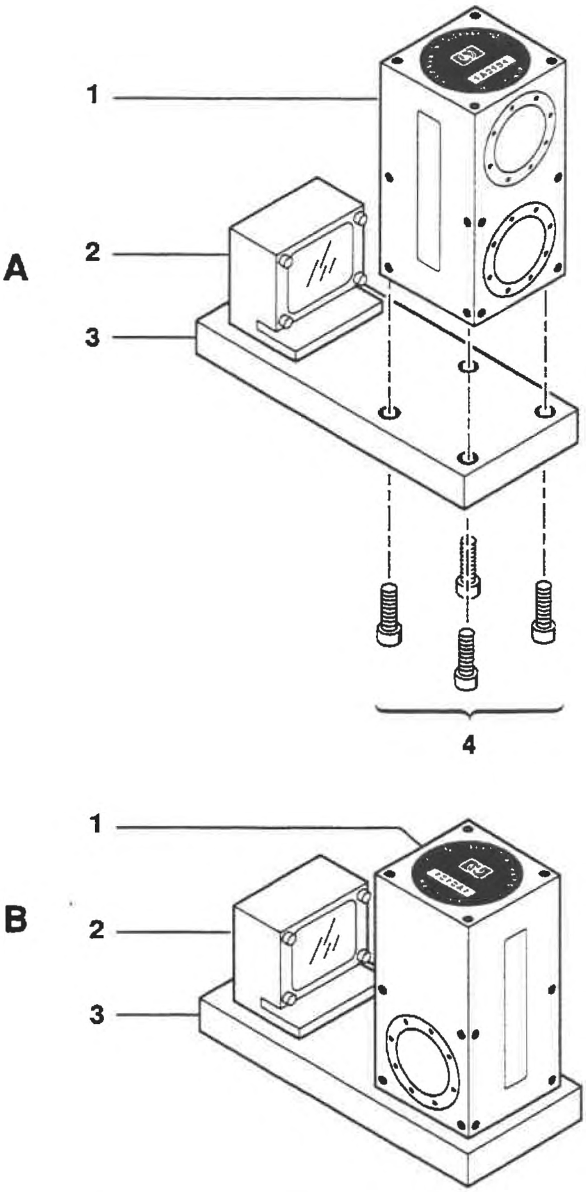


Figure 9–7. Attaching the interferometer to a flatness mirror base

The measurement line feet must be centered over the measurement line (Figure 9–6).

You are now ready to position the straightedge and mount the optics.

Mounting the optics

To mount the optics, follow these steps:

1 **Position the straightedge as shown in Figure 9–8 or 9–9.**

Leave a gap of approximately 5-mm (3/16-inch) between the straightedge and the measurement line. The gap leaves room to properly position and move the optics along the measurement line.

2 **Depending on whether or not you are using flatness mirrors, place the optics on the surface plate using the following guidelines. Figures 9–8 and 9–9 show two possible setups.**

- The side of the footspacer having two feet should be parallel to the line being measured, and the line should pass under the centers of those two feet.
- If you are using flatness mirrors, the flatness mirror that first deflects the laser beam is referred to later in the chapter as the "first flatness mirror." For one way to set up the flatness mirror when the far corners of the surface are inaccessible, see Figure 9-9.

3 **Adjust the straightedge so that it is parallel to the measurement line at both ends of the line and is flush with the edge of the footspacer facing the straightedge.**

Remember that the footspacer measurement line feet must be centered over and resting on the measurement line, as described earlier.

1 Straightedge
2 Surface plate
3 Reflector mounted on a footspacer
4 Interferometer mounted on a flatness mirror base
5 Laser head

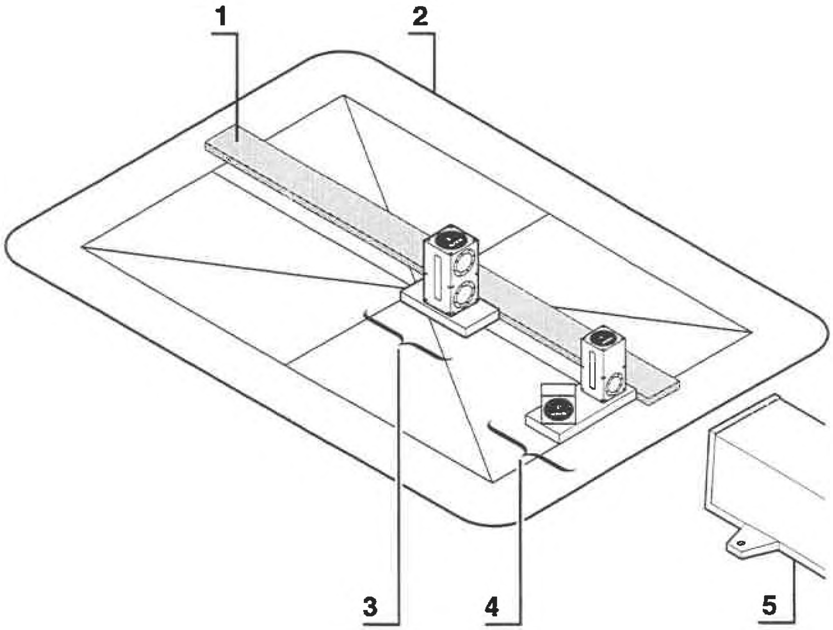


Figure 9–8. Positioning optics if flatness mirrors are not required

1 Surface plate

2 Straightedge

3 First flatness mirror

4 Laser head

5 Interferometer assembly

6 Reflector mounted on a footspacer

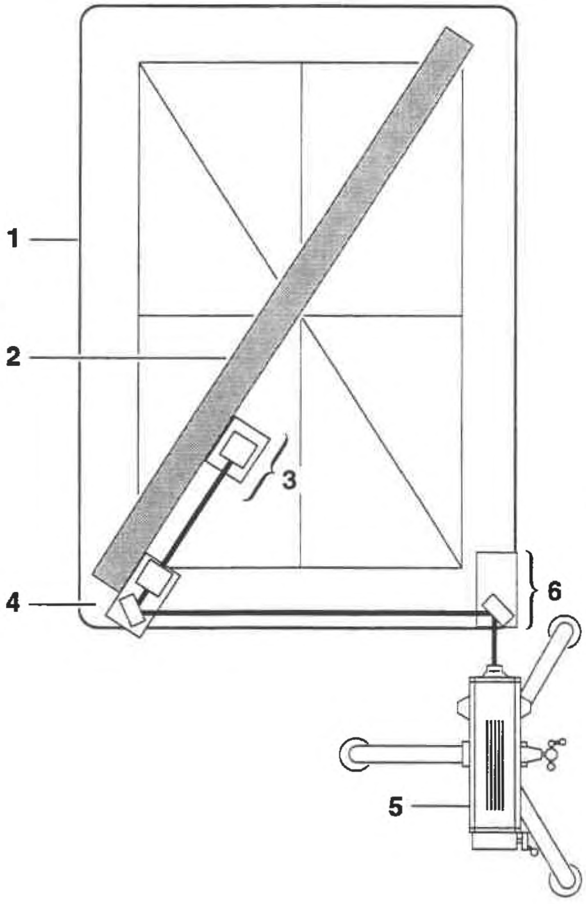


Figure 9–9. Positioning optics if flatness mirrors are required

You are now ready to position the laser head.

Positioning the laser head

After you assemble and mount the optics, you must position the laser head and place the straightedge along the first measurement line.

Note To ensure that you can properly set up the optics, the straightedge you use must be long enough to extend past the ends of the diagonals, or you may need more than one straightedge. This allows you to position the interferometer outside of the measurement grid.

Follow these steps:

1 **Position the laser head along your first measurement line.**

When positioning the laser head, follow these guidelines:

- If you can align the laser head with a measurement line, choose a line and position the laser head so it points along the line (Figure 9–10). Although Figure 9–10 uses the center line as an example, you can choose any line.
- If you cannot align the laser head with a measurement line, choose an edge and position the laser along it (Figure 9–11). Visually align the laser head so the laser beam is approximately 25-mm (1-inch) above the edge of the surface plate. The 25-mm (1-inch) gap leaves room to properly position a flatness mirror. After you have assembled and mounted the optics, you will adjust the laser head more precisely.

1 Laser head

2 Surface plate

3 Straightedge positioned along the first measurement line

4 Nameplate

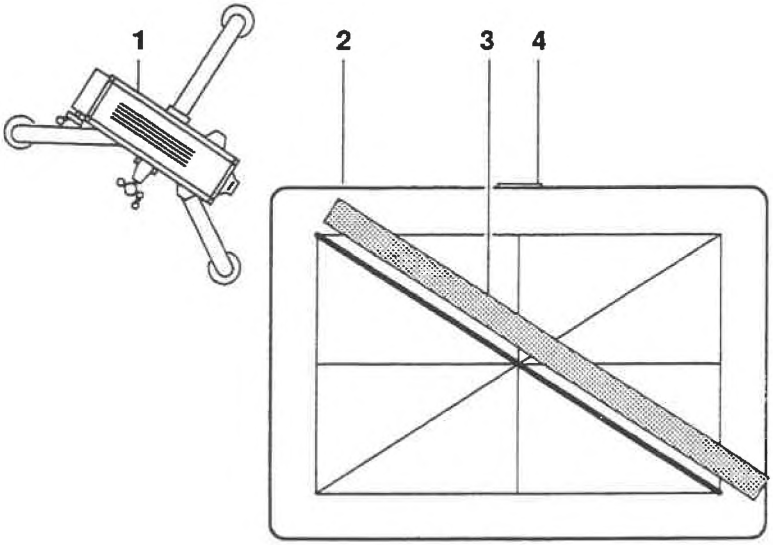


Figure 9–10. Initially positioning the laser head and straightedge if flatness mirrors are not required

1 Laser head
2 Surface plate
3 Straightedge positioned along the first measurement line
4 Nameplate
5 Flatness mirror with base

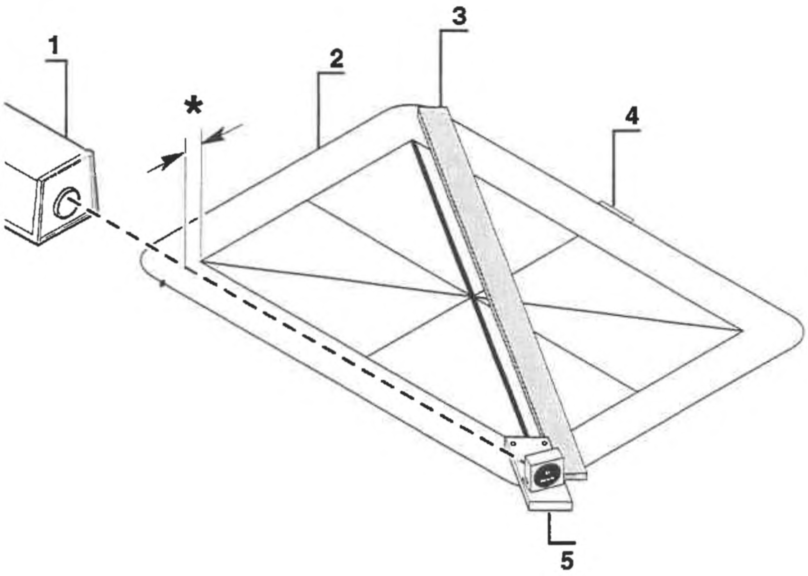


Figure 9–11. Initially positioning the laser head and straightedge if flatness mirrors are not required

2 **Adjust the laser head to the approximate height at which you will mount the optics.**

You are now ready to align the optics to the laser beam.

Aligning the optics

This section explains optics alignment procedures for setups with and without flatness mirrors. Before completing the steps in this section, ensure that the interferometer on a footspacer or interferometer assembly is flush with the straightedge and is outside the measurement grid.

Note To use these procedures, you need to know where the laser beam is, relative to an optic. To see the laser beam, you may need to hold a piece of paper in the laser beam path in front of the optic.

WARNING: Do not stare directly at the laser light beam or the beam reflected from a polished surface. (It is safe to look at the dots of light reflected on an unpolished surface.)

To align the optics, begin by following these steps:

1 **Set the laser head's upper port to the small aperture by turning the upper aperture control (Figure 2–13).**

2 **Rotate the target into position on the laser head's lower port by turning the lower aperture control (Figure 2-13).**

3 **Set the laser head's turret ring to OTHER (Figure 2-13).**

4 **Attach a target to the interferometer on the side facing the laser beam coming from the laser head so the target's crosshairs are below the target's opening and the edges of the target line up as evenly as possible with the edge of the interferometer.**

If you are not using flatness mirrors, continue with the next section, "Aligning the optics if you are not using flatness mirrors."

If you are using flatness mirrors, go directly to "Aligning the optics if you are using flatness mirrors."

Aligning the optics if you are not using flatness mirrors

To align the optics if you are not using flatness mirrors, follow these steps:

1 **Adjust the laser head so the laser beam enters the hole of the target mounted on the interferometer.**

You can adjust the laser head by pitching, yawing, or translating it, or all three.

2 **Move the reflector so its footspacer touches the interferometer assembly's base.**

3 **Adjust the laser head so:**

- **the return beam is centered on the target covering the laser head's return port, and**
- **the laser beam maintains its position in the center of the interferometer's target**

You can adjust the laser head by tilting, turning, or translating it, or all three.

You are now ready to align the laser beam to the optics' travel path. Go directly to "Aligning the laser beam to the optics' travel path."

Aligning the optics if you are using flatness mirrors

This section explains how to align the optics using either one or two flatness mirrors.

1 **Align the laser head so the beam strikes the first flatness mirror.**

If you are using just one flatness mirror, align the laser head so the beam strikes the center of that flatness mirror.

2 **Move the reflector so its footspacer touches the interferometer assembly's base.**

3 **Position the flatness mirror.**

- If you are using two flatness mirrors, turn the first flatness mirror so the laser beam is vertically in line with the flatness mirror on the interferometer assembly. Continue with step 4.
- If you are using just one flatness mirror, turn it so the beam is vertically in line with the hole in the interferometer's target. Then, skip to step 6.

4 **Tilt the laser head so the beam enters the flatness mirror on the interferometer assembly.**

If the beam moves out of the first flatness mirror, translate the laser head vertically until the beam enters the first flatness mirror again.

5 **Turn the flatness mirror on the interferometer assembly so that the beam is vertically in line with the hole in the interferometer's target.**

6 **Translate the laser head vertically so the beam enters the hole in the interferometer's target.**

7 **Remove the target from the interferometer.**

8 **Turn the flatness mirror on the interferometer assembly so that the return beam is vertically in line with the target covering the laser head's return port.**

If this causes the beam to move out of the hole on the interferometer's target, rotate the flatness mirror so the beam maintains its position in the target's hole.

9 **Tilt the laser head up or down until the return beam centers on the target covering the laser head's return port.**

Be sure the beam maintains its position in the center of the flatness mirror and the target's hole.

10 **Secure the first flatness mirror and the interferometer assembly to the surface plate, maintaining the return beam's position in the center of the laser head's target.**

You are now ready to align the laser beam to the optics' travel path.

Aligning the laser beam to the optics' travel path

Follow the instructions in "Aligning the laser beam to the machine's travel path for long-range measurements" in Chapter 2. However, note these exceptions:

- Use the procedures in Chapter 2 regardless of the length of your measurement line.
- Instead of moving the machine's moveable part, move the reflector.

You are now ready to complete the Set Up Flatness screen.

Completing the Set Up Flatness screen

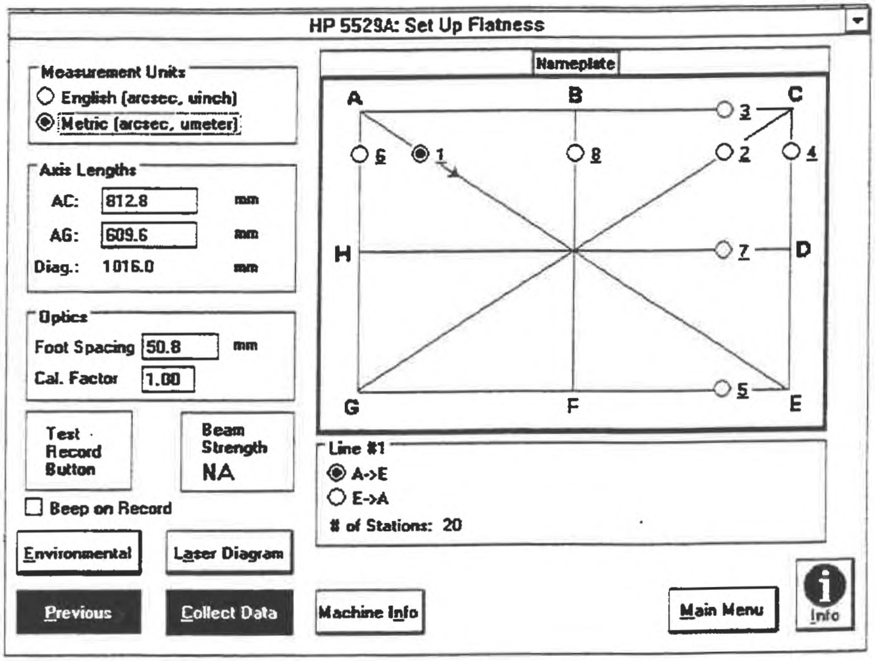
Before checking the alignment for beam strength, you must complete the Set Up Flatness screen. This screen allows you to supply the software with general measurement setup information, such as the footspacer length. To complete this screen, follow these steps:

1 **On the Other Measurements screen, select Flatness.**

The Set Up Flatness screen is displayed (Figure 9–13).

2 **In the Measurement Units box, select either English or Metric.**

Your selection indicates the units for angles and for footspacer and line lengths. It also determines the display units for the diagonal length on the Set Up Flatness screen and the Laser Error and Target position units on the Collect Data: Flatness screen.



HP 5529A: Set Up Flatness
Nameplate
A
B
C
D
E
F
G
H
1
2
3
4
5
6
7
8
Test Record Button
Beam Strength
NA
Environmental
Laser Diagram
Previous
Collect Data
Machine Info
Main Menu
Info

Measurement Units
○ English (arcsec, uinch)
● Metric (arcsec, umeter)

Axis Lengths
AC: 812.8 mm
AG: 609.6 mm
Diag.: 1016.0 mm

Optics
Foot Spacing 50.8 mm
Cal. Factor 1.00

☐ Beep on Record

Line #1
● A->E
○ E->A
# of Stations: 20

Figure 9–13. Set Up Flatness screen

3 In the Axis Lengths box, enter the lengths of perimeter lines 3 and 6 (see figure 9–3 or 9–4).

You can enter data into either field first. Whenever you enter data in either box, the diagonal field goes blank. The diagonal data redisplays when you press Enter or tab out of this field.

After you complete both fields, the software calculates the length of the diagonal and displays it below the AG field.

4 In the Optics box, do the following:

a In the Foot Spacing field, enter the size of the footspacer you chose.

b If your interferometer has a calibration factor stamped on it, enter the factor here. Otherwise, leave this field at 1.

Your optics will only have a calibration factor if you have had them calibrated. This calibration provides accuracy within 0.2% of your reading.

5 **Select the line you plan to measure by clicking the corresponding numbered button.**

Be sure that the number of stations in the Line Setup box equals the number of stations for that line on your measurment grid. If it does not, recheck your footspacer and line lengths.

Note If you have already measured one or more lines, these lines are grayed out. If you want, you can select one of these lines to measure again, for example, to average the measurement data with the existing data.

After you select a line, the number of stations on the line is displayed in the Line Setup box.

If you selected a line that you have already measured, an option box is displayed in the Line Setup box.

6 **In the Line Setup box, do the following:**

a Indicate the optic's direction of travel for this measurement by selecting the appropriate button on the left side of the Line Selection box.

b If you selected a line that you have already measured, indicate how you want the software to process the measurement data you are about to collect:

- To overwrite the existing data with the data you are about to collect, select Overwrite Existing Data.
- To average the data you are about to collect with the existing data, select Average with Existing Data.

You are now ready to check the alignment for beam strength.

Checking the alignment for beam strength

Before completing the steps in this section, ensure that the reflector is at its initial position.

1 **Set the laser head's upper port to the large aperture.**

2 **Move the reflector along the travel path and check the Beam Strength indicator button on the Set Up Flatness screen.**

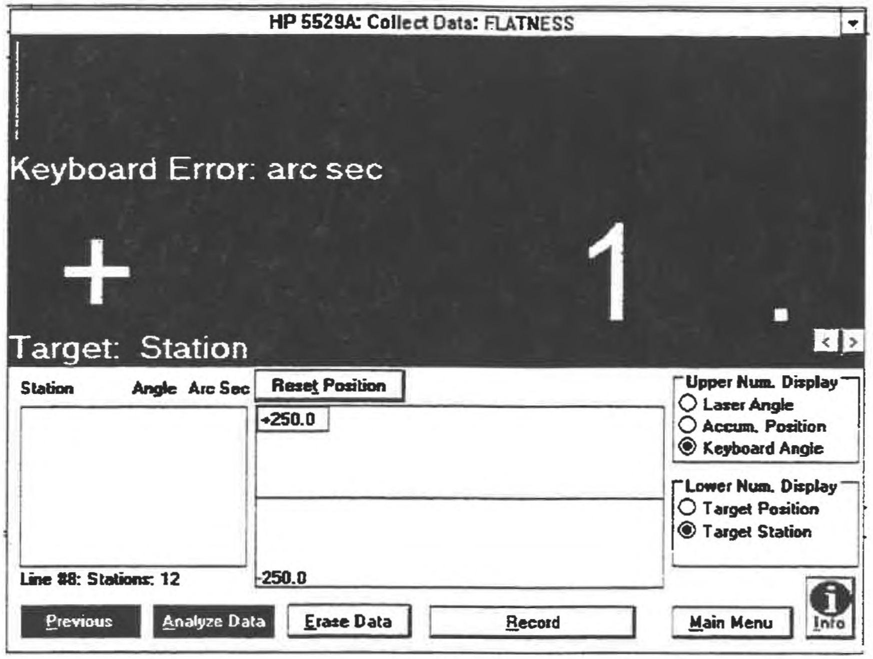
- If the beam strength is greater than 60 percent (and the indicator area is green if you have a color monitor), go directly to "Making the measurement."

- If the beam strength is 20 to 60 percent (and the indicator area is yellow if you have a color monitor), you can make the measurement, but you risk losing the laser beam return signal during a measurement. If you lose the signal during a measurement, you will have to improve the laser beam alignment and take data starting at the last valid point. You may want to follow the steps in "Improving beam strength." Otherwise, go directly to "Making the measurement."

- If the beam strength is less than 20 percent (and the indicator area is red if you have a color monitor), follow the steps in "Improving beam strength."

When you have completed the Set Up Flatness screen, choose Collect Data.

The Collect Data: Flatness screen is displayed (Figure 9–14).



HP 5529A: Collect Data: FLATNESS

Keyboard Error: arc sec

+ 1 .

Target: Station

Line #8: Stations: 12

Upper Num. Display
○ Laser Angle
○ Accum. Position
● Keyboard Angle

Lower Num. Display
○ Target Position
● Target Station

Figure 9–14. Collect Data: Flatness screen

Improving beam strength

To improve beam strength, do the following:

- The optics are positioned so that the laser beam passes cleanly through the optics (figures 9–8 and 9–9, or 9-16 through 9–18). If they are not, repeat the steps in "Mounting the optics."
- The optics are securely assembled and mounted. If they are not, remount the optics, tighten the attachment screws, and repeat the steps in "Aligning the optics."
- The optics are clean. To clean the optics, follow the directions in the *HP 5529A Getting Started Guide*.

If you cannot obtain 60 percent beam strength, call your local support person or Hewlett-Packard customer support. Refer to the *HP 5529A Getting Started Guide* for a list of Hewlett-Packard service and support centers.

Making the measurement

In this procedure, you make manual measurements as you move the reflector. This section explains how to make measurements using the Record button in the software and on the optional remote control unit.

Before making your measurement, check two things:

- The repeatability of the optics at rest—Be sure that the reading displayed does not change when the optics are still. If the display does change, do the following:
  - Ensure that the footspacer is sitting flat on the surface plate.
  - The optic is securely fastened to the footspacer.
  - The surface plate is clean.
  - The optics are thermally stable—15 ° to 25 °C (59 ° to 77 °F)
- The optics coming to rest at a station—Check your measurement's repeatability by stopping at each station along the travel path and looping back to the previous station to ensure that the readings are the same. There will be some variation since you are manually moving the optics, but try to place the optics in the same spot each time.

Non-repeatable readings can also be caused by dirt, dust, or granite flakes under the feet.

Measuring the first line on the grid

To make the measurement, follow these steps:

1. **Move the reflector to the first station.**
2. **On the Collect Data: Flatness screen, select Reset Position.**

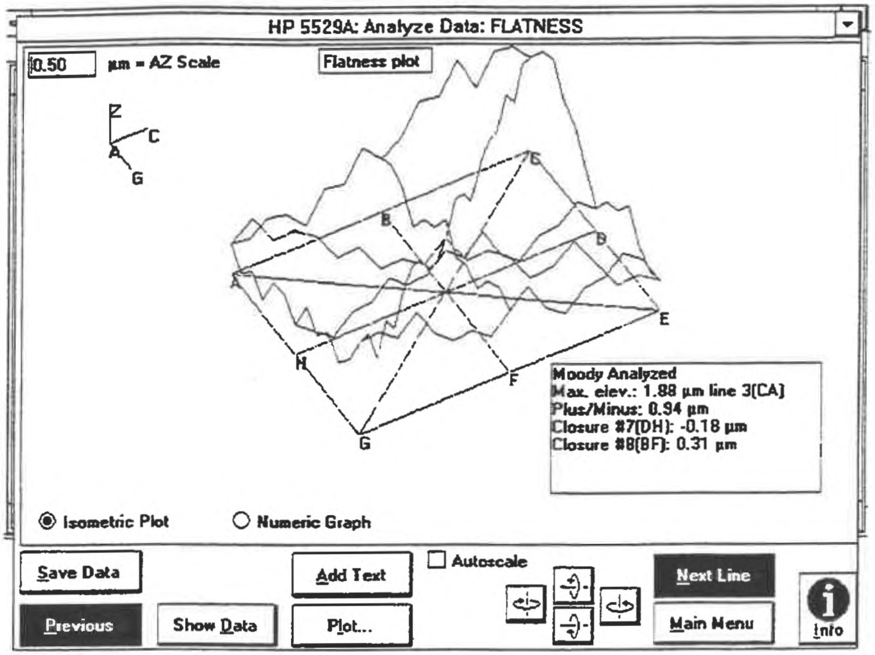
   This tells the system that the current position of the reflector is the "zero" point from which the surface plate flatness will be measured (that is, the first data point for this line).

   If necessary, use the online help to complete the rest of the fields on this screen.
3. **Select Record.**

   If you are using the optional remote control unit, press the Record button.
4. **Move the reflector to the second data point on the line to be measured.**
5. **Select Record.**
6. **Continue, moving the reflector to each station along the line and recording measurements until you have recorded data at the last station on the line.**

   After the last measurement on each line is recorded, the Analyze Data: Flatness screen is displayed (Figure 9–15).

Note If at any point the Reset Laser message flashes, the laser beam path has been broken. Move the reflector back to the first point measured, then select Reset Position to reset the system. Now you can return to the last station you measured (check your repeatability) and continue taking measurements.


HP 5529A: Analyze Data: FLATNESS
0.50
µm = AZ Scale
Flatness plot
Z
C
A
G
B
C
D
A
E
H
F
G
● Isometric Plot
○ Numeric Graph
Save Data
Previous
Show Data
Add Text
Plot...
☐ Autoscale
Next Line
Main Menu
Info

Moody Analyzed
Max. elev.: 1.88 µm line 3[CA]
Plus/Minus: 0.94 µm
Closure #7(DH): -0.18 µm
Closure #8(BF): 0.31 µm

Figure 9–15. Analyze Data: Flatness screen

7 **If you wish to create or update a data file with the measurement data, select Save Data on the Analyze Data: Flatness screen.**

Refer to "Analyzing flatness measurement data" later in this chapter for more information about using this screen or the online help for a description of the fields on this screen.

8 **To measure the remaining lines on the grid, press Next Line.**

The Setup Flatness screen displays. Continue with the next section, "Measuring the remaining lines on the grid."

Measuring the remaining lines on the grid

To measure the remaining lines on the grid, follow these steps:

1 **If you have not already done so, select Next Line on the Analyze Data: Flatness screen.**

The Set Up Flatness screen (Figure 9–13) is displayed.

You can change the measurement units and optic's direction of travel on the Set Up Flatness screen using the instructions in "Completing the Set Up Flatness screen," earlier in this chapter.

2 **If you are not using flatness mirrors, move the laser head so it points along the next measurement line.**

If you are using flatness mirrors, continue with step 4.

3 **Set up the optics for the measurement.**

If you are not using flatness mirrors, set up the optics using the appropriate instructions in "Mounting the optics" and "Aligning the optics" earlier in this chapter.

If you are using flatness mirrors, set up the optics using one of the setups shown in Figures 9–16 through 9–18.

4 **Align the optics using the instructions in "Aligning the optics," earlier in this chapter.**

5 **Align the laser beam to the optics' travel path using the instructions in "Aligning the laser beam to the optics' travel path," earlier in this chapter.**

6 **Check the alignment for beam strength using the instructions in "Checking the alignment for beam strength," earlier in this chapter.**

7 **Repeat the steps in "Measuring the first line on the grid."**

8 **Repeat steps 1 through 8 in this section until you have measured all of the measurement lines.**

When the Analyze Data: Flatness window displays after you measure the last line, continue with the steps in "Analyzing flatness measurement data."

1	Laser head
2	Straightedge
3	Interferometer assembly
4	First flatness mirror
5	Reflector mounted on a footspacer

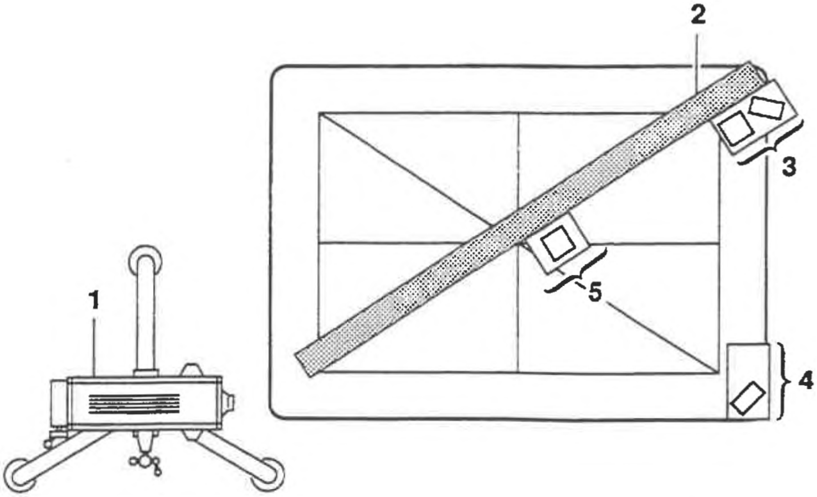


Figure 9–16 Positioning optics for measuring diagonal lines (lines 1 and 2) when using flatness mirrors

1 Laser head

2 Interferometer assembly

3 Reflector mounted on a footspacer

4 Straightedge

5 First flatness mirror

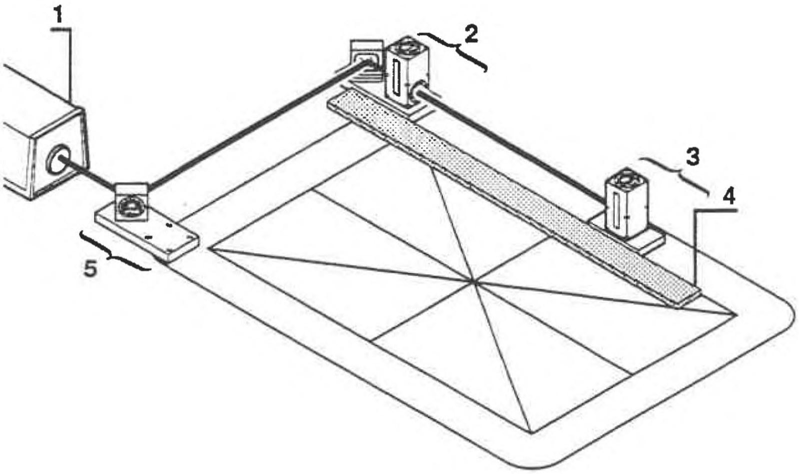


Figure 9–17. Positioning optics for measuring lines parallel to the laser head (lines 3, 5, and 7) when using flatness mirrors

1 Laser head

2 Interferometer assembly

3 Reflector mounted on a footspacer

4 Nameplate

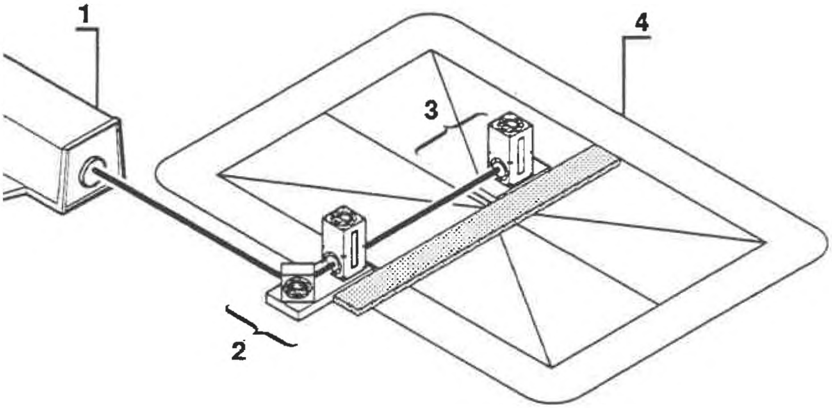


Figure 9–18. Positioning optics for measuring lines perpendicular to the laser head (lines 4, 6, and 8) when using flatness mirrors

Analyzing flatness measurement data

The Analyze Data: Flatness screen presents a graphical data display and a numerical analysis of the measurement data set. You can display data in two formats: isometric and numeric.

- To view data in the graphic format, select Isometric Plot from the option box above the Save Data button in the lower left corner of the screen.
- To view data in the numeric format, select Numeric Graph from the option box above the Add Text button in the lower left corner of the screen.

As with Analyze Data screens for all other measurements, you can use this screen to display the measurement dataset. To do this, select Show Data (or press Alt D).

Understanding the isometric format

The isometric format shows the measurement grid with an isometric plot of the measurement data. (See Figure 9–15.) The functions available with this format are explained below.

Rotating the grid and plot

At the bottom of the screen, below the Autoscale checkbox, are four rotation buttons. Use these to rotate the grid and plot vertically and horizontally to show different views of the display.

Because rotating the grid and plot can hide line identification letters and make it difficult to know how the grid and plot are oriented, the three axes below the AZ Scale box show the current orientation of the grid and plot. As you rotate the grid and plot, the three axes rotate.

Changing the AZ axis scale

To better view the plot of the measurement data, you can change the AZ axis scale. The distance in the AZ scale box is equivalent to the length of the AZ segment immediately below it. The isometric graph is plotted using the same AZ scale. This exaggerates the distance of the plot from the grid, making it easier to see how the measurement data deviates from the zero point.

Use the AZ Scale box to change the AZ axis scale. To change the AZ axis scale, do the following:

1 **Place the cursor in the AZ Scale box.**

2 **Enter a number from .001 to 1000, then press Enter.**

If you want, you can let the software automatically change the AZ axis scaling to an optimal value. To do so, select the Autoscale checkbox. This checkbox is at the bottom of the screen to the right of the Add Text button.

Typing measurement comments

In the upper right corner of the screen is a box in which you can type comments or other information pertinent to the measurement. To enter information in this box, select the Add Text button (or press Alt A).

If necessary, you can move the box. To do so, place the cursor in the box, press the mouse button, drag the box to where you want to move it, then release the mouse button.

Viewing data analysis results

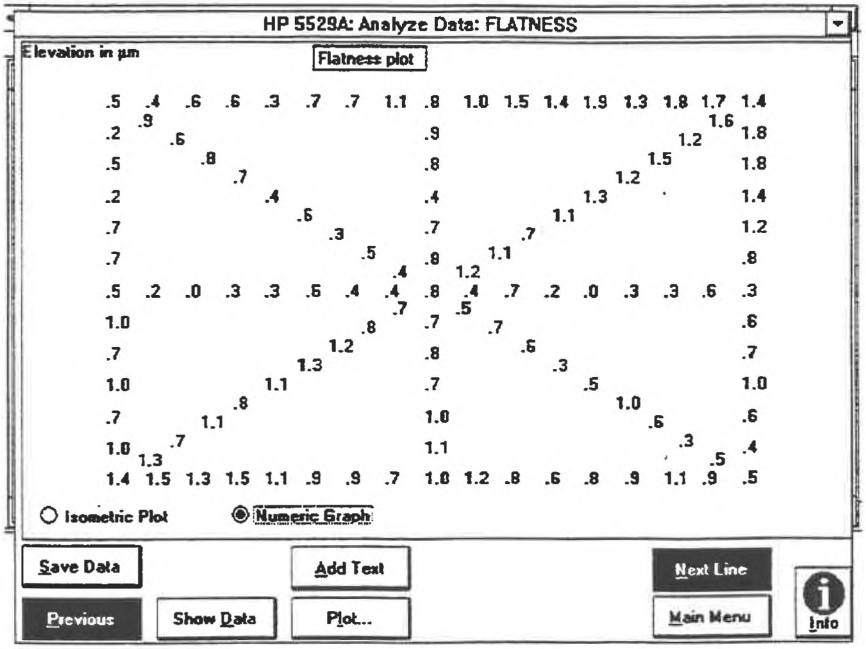
Below the grid is a box that gives the following measurement analysis information:

- the greatest vertical deviation from the zero point and the line that contains this deviation

- the closure error for lines 7 and 8

Understanding the numeric format

The numeric format presents a two dimensional view of the measurement grid. (See Figure 9–19.) Each measurement point is marked by the value of the data obtained at that point. Unlike the isometric format, you cannot change the appearance of this grid. The AZ Scale box, Autoscale checkbox, and rotation buttons are grayed out when you view data in the numeric format.


HP 5529A: Analyze Data: FLATNESS
Elevation in µm
Flatness plot
○ Isometric Plot
● Numeric Graph
Save Data
Add Text
Next Line
Previous
Show Data
Plot...
Main Menu
Info

```
.5   .4   .6   .6   .3   .7   .7   1.1  .8   1.0  1.5  1.4  1.9  1.3  1.8  1.7  1.4
    .9                                                                      1.6
.2      .6                              .9                              1.2     1.8
            .8                                                      1.5
.5                                      .8                                      1.8
                .7                                              1.2
.2                  .4                  .4                  1.3                 1.4
                        .6                              1.1
.7                                      .7                                      1.2
                            .3                      .7
                                .5              1.1
.7                                      .8                                      .8
                                    .4      1.2
.5   .2   .0   .3   .3   .6   .4   .4   .8   .4   .7   .2   .0   .3   .3   .6   .3
                                    .7      .5
1.0                                     .7                                      .6
                                .8              .7
                            1.2                     .6
.7                                      .8                                      .7
                        1.3                             .3
1.0                 1.1                 .7                  .5                  1.0
                .8                                              1.0
.7          1.1                         1.0                         .6          .6
        .7                                                              .3
1.0                                     1.1                                     .4
    1.3                                                                     .5
1.4  1.5  1.3  1.5  1.1  .9   .9   .7   1.0  1.2  .8   .6   .8   .9   1.1  .9   .5
```

Figure 9–19. Analyze Data: Flatness screen in numeric format

10. Way straightness Measurements

10. Way straightness Measurements

10

Way Straightness measurements

Way Straightness measurements

This chapter explains how to make way straightness measurements at multiple points along a machine part such as a milling machine way. Since most of the procedures for way straightness measurements are similar to those for flatness measurements, you are referred to Chapter 9 for certain instructions.

Before performing the procedures described in this chapter, you must fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*. For measurement operating specifications, see the way straightness measurement specifications in Appendix A. Since you use the angular interferometer and reflector to make way straightness measurements, see the angular measurement specifications in Appendix A for optics specifications.

Figure 9–1 shows the required optics and mounting hardware for way straightness measurements.

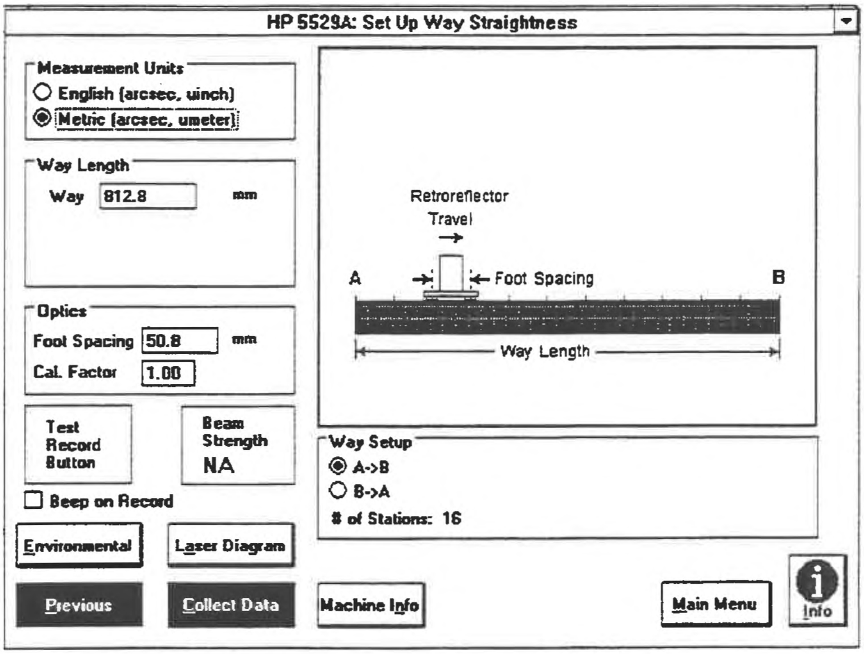
Setting up for the measurement

To set up for the measurement, follow these steps:

1 **Follow steps 1 through 5 in "Setting up for the measurement" in Chapter 9.**

2 **Select Way Strat from the Other Measurements screen.**

The Set Up Way Straightness screen is displayed (Figure 10-1).


HP 5529A: Set Up Way Straightness
Retroreflector
Travel
A
Foot Spacing
B
Way Length
Test Record Button
Environmental
Laser Diagram
Previous
Collect Data
Machine Info
Main Menu
Info

Measurement Units
○ English (arcsec, uinch)
● Metric (arcsec, umeter)

Way Length
Way 812.8 mm

Optics
Foot Spacing 50.8 mm
Cal. Factor 1.00

Beam Strength NA

☐ Beep on Record

Way Setup
● A->B
○ B->A
# of Stations: 16

Figure 10–1. Set Up Way Straightness screen

Marking footspacer intervals

To make measurements along the machine way, you must mark measurement points, called "stations" on the way. First, choose a footspacer for the interferometer. The footspacer kit includes three footspacers: 50-mm (2-inches), 102-mm

(4-inches), and 152-mm (6-inches). These sizes are actually the distances between the leading and trailing feet of the footspacers rather than the overall length of the footspacers.

When choosing a footspacer, remember that the smaller the footspacer, the longer it will take you to perform the entire measurement process, but the better your measurement resolution will be.

After you choose a footspacer, mark the stations on the machine way. Make sure that the interval between the marks on the way is the same as the distance between the leading and trailing feet on the chosen footspacer.

After you have marked the stations, calculate the combined length of the stations in millimeters or inches. Write down this length; you enter it on the Set Up Way Straightness screen.

Note The figures in this chapter use a milling machine way as an example. Although the equipment or machinery you are checking for way straightness may be different, the procedures described here still apply.

Assembling, mounting, and aligning the optics on the target machine

To assemble, mount, and align the optics on the target machine, follow these steps:

1 **To assemble the optics, attach the interferometer and reflector to footspacers (Figure 9–7).**

2 **Mount the optics on the machine way (Figure 10–2).**

Note You may need to make a special holder, similar to a way bearing, that follows the way and carries the reflector during the measurement. This also allows you to measure side to side flatness.

3 **To align the optics, follow the instructions in “Aligning the optics” then “Aligning the optics if you are not using flatness mirrors” in Chapter 9.**

Positioning the laser head

Position the laser head at one end of the way you plan to measure (Figure 10–2).

1	Angular reflector mounted on a footspacer
2	Angular interferometer
3	Laser head
4	Machine way

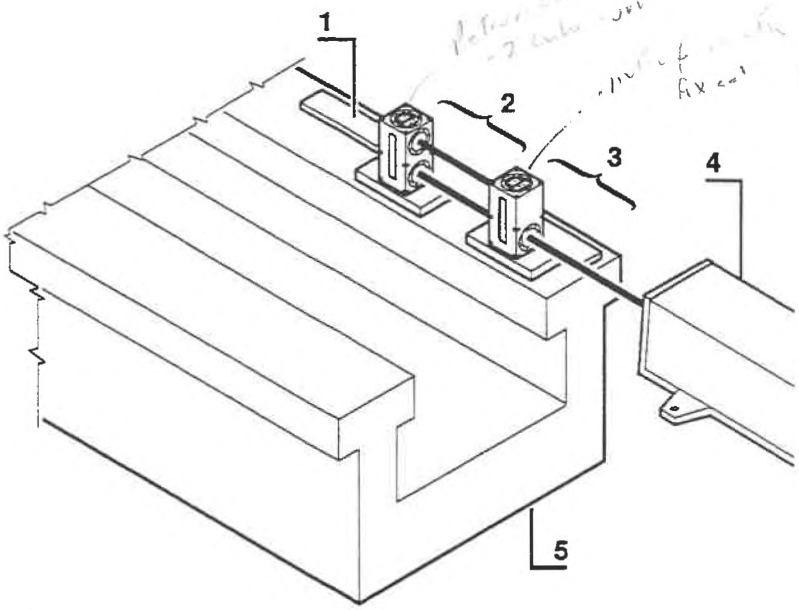


Figure 10–2. Positioning optics for a way straightness measurement

Aligning the laser beam to the optics' travel path

Follow the instructions in "Aligning the laser beam to the machine's travel path for long-range measurements" in Chapter 2. However, note these exceptions:

- Use the procedures in Chapter 2 regardless of the length of your measurement line.
- Instead of moving the machine's moveable part, move the reflector.

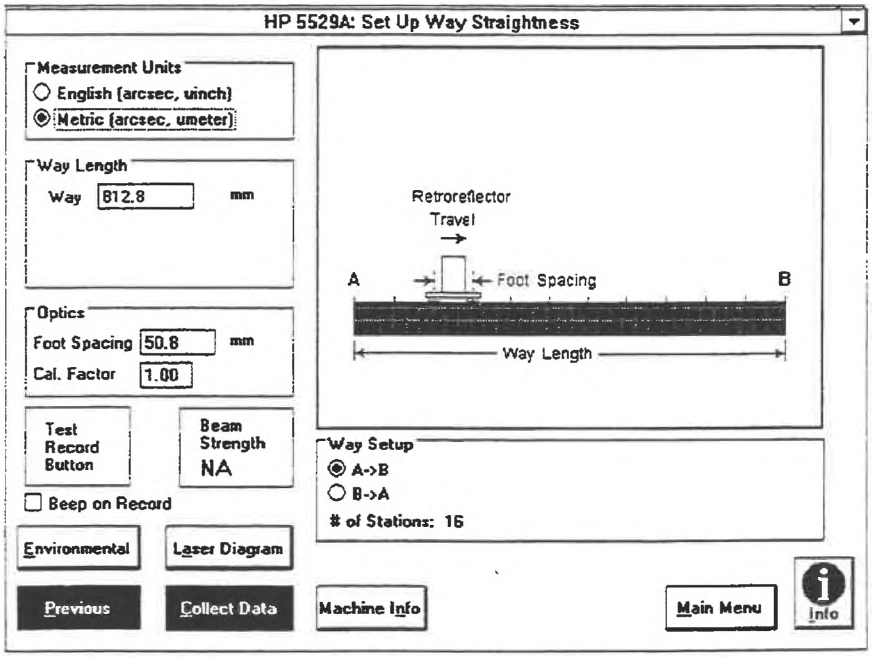
You are now ready to complete the Set Up Way Straightness screen.

Completing the Set Up Way Straightness screen

This screen allows you to supply the software with general measurement setup information, such as the footspacer length. To complete this screen, follow these steps:

1 **On the Other Measurements screen, select Way Strat.**

The Set Up Way Straightness screen is displayed (Figure 10-3).



HP 5529A: Set Up Way Straightness

Measurement Units
○ English (arcsec, uinch)
● Metric (arcsec, umeter)

Way Length
Way 812.8 mm

Optics
Foot Spacing 50.8 mm
Cal. Factor 1.00

Beam Strength NA

☐ Beep on Record

Way Setup
● A->B
○ B->A
# of Stations: 16

Test Record Button
Environmental
Laser Diagram
Previous
Collect Data
Machine Info
Main Menu
Info
Retroreflector Travel
A
Foot Spacing
B
Way Length

Figure 10–3. Set Up Way Straightness screen

2 **Complete the fields on this screen using the applicable instructions in “Completing the Set Up Flatness screen.” However, in the Way Length field, type the combined length of the stations you marked on the way.**

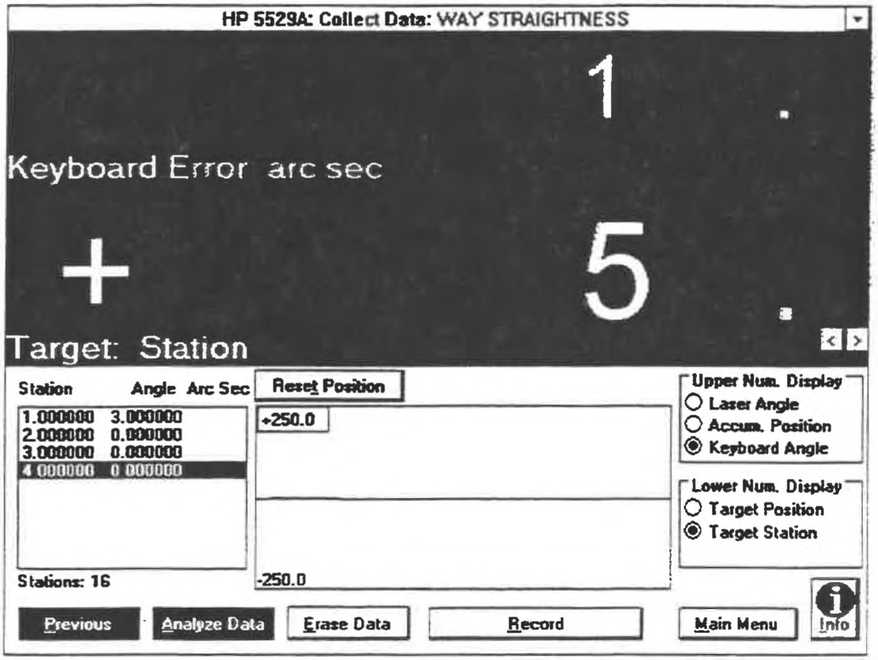
You are now ready to check the alignment for beam strength.

Checking the alignment for beam strength

To check the alignment for beam strength, follow the instructions in "Checking the alignment for beam strength" in Chapter 9. However, note these differences:

- The Set Up Way Straightness screen (Figure 10–4) is used instead of the Set Up Flatness screen. Check this screen for the beam strength.
- If you have inadequate beam strength, ensure that the optics are positioned as shown in Figure 10–2.When you have completed the Way Straightness Set Up screen, choose Collect Data.

The Collect Data: Way Straightness screen displays (Figure 10–4).



HP 5529A: Collect Data: WAY STRAIGHTNESS

Keyboard Error arc sec

1 .

+ 5 .

Target: Station

Station	Angle Arc Sec
1.000000	3.000000
2.000000	0.000000
3.000000	0.000000
4.000000	0.000000

Stations: 16

+250.0

-250.0

Upper Num. Display
○ Laser Angle
○ Accum. Position
● Keyboard Angle

Lower Num. Display
○ Target Position
● Target Station

Figure 10–4. Collect Data: Way Straightness

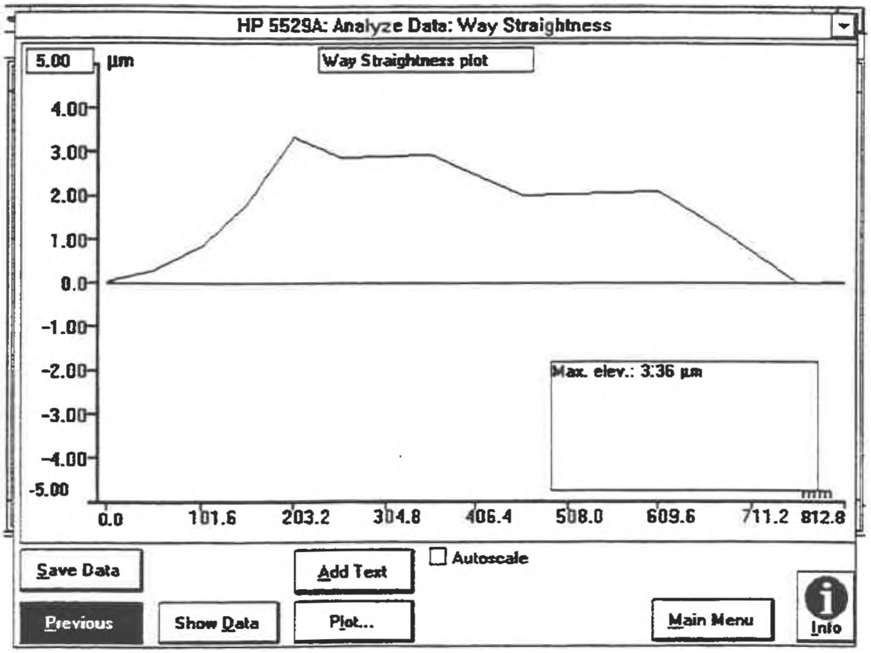
Making the measurement

To make the measurement, follow the instructions in "Making the measurement" in Chapter 9. However, note these differences:

- Use the Reset Position and the Record buttons on the Collect Data: Way Straightness screen (Figure 10–4) instead of on the Collect Data: Flatness screen.

- After you record the last measurement, the Analyze Data: Way Straightness screen (Figure 10–5) is displayed. To create a data file with the measurement data or to update an existing data file, select Save Data on this screen. Refer to the *HP 5529A Getting Started Guide* and online help for more information about using this screen.

- Ignore the instructions in "Measuring the remaining lines on the grid" in Chapter 9.


HP 5529A: Analyze Data: Way Straightness
5.00
µm
Way Straightness plot
4.00
3.00
2.00
1.00
0.0
-1.00
-2.00
-3.00
-4.00
-5.00
0.0
101.6
203.2
304.8
406.4
508.0
609.6
711.2
812.8
mm
Save Data
Add Text
☐ Autoscale
Previous
Show Data
Plot...
Main Menu
Info

Max. elev.: 3.36 µm

Figure 10–5. Analyze Data: Way Straightness

User's Guide

Note: This User's Guide is intended for use
as Chapter 11 in an
HP 5529A Dynamic Calibrator
Measurements Reference Guide.

11. Diagonal Measurements

HP 10768A Diagonal Measurement Kit
HP 10769A Beam Steering Mirror
HP 10767B Lightweight Retroreflector
HP 10744A Accessory Kit

11. Diagonal Measurements

User's
Guide

Note: This User's Guide is intended for use as Chapter 11 in an HP 5529A Dynamic Calibrator *Measurements Reference Guide*.

HP 10768A Diagonal Measurement Kit
HP 10769A Beam Steering Mirror
HP 10767B Lightweight Retroreflector
HP 10744A Accessory Kit

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Rev E, NOV 1994

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About this guide

This guide is formatted to be inserted as Chapter 11 of an HP 5529A *Measurements Reference Guide*. A standalone 8-1/2 × 11-inch version is also available.

The table of contents and index included are for this chapter only. No attempt has been made to incorporate these entries into the table of contents or index of the HP 5529A *Measurements Reference Guide*.

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11

Diagonal Measurements

Diagonal Measurements

This chapter explains how to set up hardware to make a diagonal measurement using the HP 5529A Dynamic Calibrator. After the hardware setup has been made, you use the HP 5529A's Linear measurement function to collect your measurement data. Think of it as making a linear measurement along a line that is not necessarily parallel to or perpendicular to any of the machine's major axes. Before performing the procedures described in this chapter, you must fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*.

Background—Why Diagonal Measurements?

The goal in calibrating a machine tool or coordinate measuring machine (CMM) is to determine its volumetric accuracy—that is, its ability to position accurately anywhere in the work zone. This cannot be done directly, but can be inferred by measuring the six degrees of freedom for each axis and the squareness of X, Y, and Z to each other. This can be a time-consuming process, and in many cases the time spent is not justified. Thus, there is a need for a quick assessment of volumetric performance.

Measurement of work zone diagonals provides just such an assessment. As the spindle is traversed along a body diagonal of the work zone, all axes must move in concert in order to position accurately along the line. Diagonal measurements are useful in machine tool acceptance testing or in a periodic maintenance program to quickly assess the condition of a machine.

The HP 10768A Diagonal Measurement Kit is an optical accessory to the HP 5529A Dynamic Calibrator. It enables precise alignment of the laser beam to the body diagonals of the work zone of a milling machine or CMM. It also simplifies calibration of slant-bed lathes. The optics can be repeatedly aligned to the same machine diagonals at future calibrations. The HP 10768A enables implementation of ANSI/ASME standards B89 and B.5 for CMMs and machine tools, respectively.

HP 10768A Diagonal Measurement Kit

The HP 10768A Diagonal Measurement Kit provides hardware that allows you to use Hewlett-Packard linear measurement optics (see Figure 11–2) in an HP 5529A Dynamic Calibrator or an HP 5528A Laser Measurement System to make distance measurements along any linear machine travel path.

A diagonal measurement is a linear displacement measurement along a line that is not necessarily parallel to nor perpendicular to one or more of the orthogonal major axes (X, Y, and Z) of the machine being calibrated. A typical diagonal measurement path is the body diagonal of a work zone (see Figure 11-3). A typical use for a diagonal measurement is to assess the volumetric performance of a machine tool or coordinate measuring machine. See ANSI/ASME Standard B.5.54 for additional information about assessing volumetric performance using diagonal measurements.

The HP 10768A kit can also be used to simplify the calibration of a slant-bed lathe, as described under the "HP 10769A ..." heading below.

Much of the basic information you should know in order to perform a diagonal measurement is contained in the Linear or Distance Measurements chapter of your Laser System user documentation.

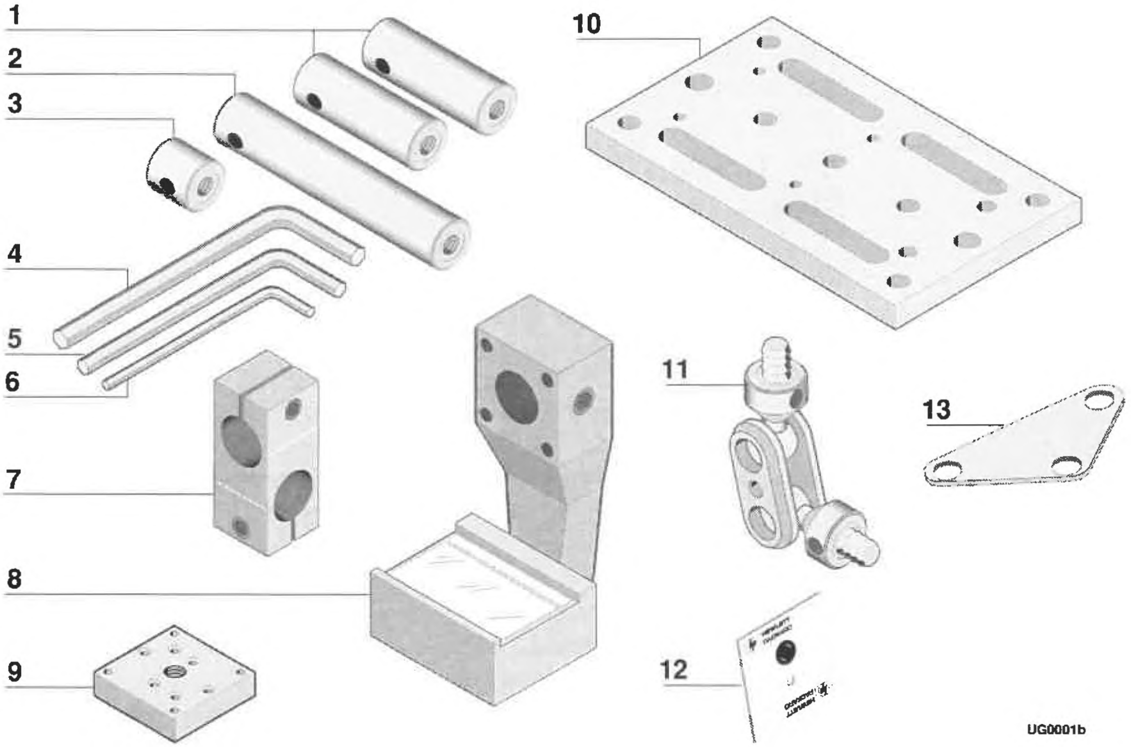
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Figure 11–1. HP 10768A Diagonal Measurement Kit (Part 1 of 2)

Reference Number	Description	HP Part Number	Quantity in HP 10768A	Quantity in HP 10769A	Quantity in HP 10744A
1	post-medium	10776-20008	2	0	2
2	post-long	10785-20005	1	1	5 (Option 005 adds 5)
3	post-stub	10768-20213	1	0	2
4	hex key 5 mm	8710-2040	1	1	1
5	hex key 4 mm	8710-2041	1	1	1
6	hex key 2.5 mm	8710-1181	1	1	1
7	right-angle clamp	10768-20207	2	0	3
8	beam-steering assembly	10768-60201	1	1	0
9	adapter plate	10768-20215	2	0	1
10	base-large	10768-20214	1	1	1
11	flexible ball-joint assembly	10768-60203	1	0	1
12	alignment target	10767-67001	1	1	0
13	gusset	10744-00001	0	0	3
not shown	lens tissue	9281-0363	1 pkg	1 pkg	1 pkg
not shown	adjustable triangle	9300-1730	1	0	0
not shown	setscrew–brass tip, M10×1.5	0515-2336	1	1	0
not shown	setscrew–brass tip, M5×0.8	0515-2358	1	1	0
not shown	cap screw-socket-head-M3×25 long	0515-2359	4	4	4
not shown	setscrew M10×20	0515-2362	1	0	3
not shown	flathead screw-M3×0.5×16 long	0515-0078	4	0	2

Figure 11–1. HP 10768A Diagonal Measurement Kit (continued)

HP 10769A Beam Steering Mirror

The HP 10769A Beam Steering Mirror provides the beam-steering hardware from the HP 10768A kit, along with some mounting hardware. This combination of parts allows you to deflect a laser beam at any angle, in either the vertical or the horizontal polarization plane of the beam. One use of this hardware is for laser measurements and calibration of slant bed lathes. In this case, the beam steering mirror is used to deflect the beam from the laser head upward, through the interferometer, along the lathe's cross slide; the other measurement optics and hardware can be the same as for standard measurements.

You can use one or more HP 10769A mirrors to create a path from the laser head to an interferometer in an otherwise inaccessible position. A typical use is with the HP 10768A Diagonal Measurement Kit on a milling machine in which the table moves in only one axis.

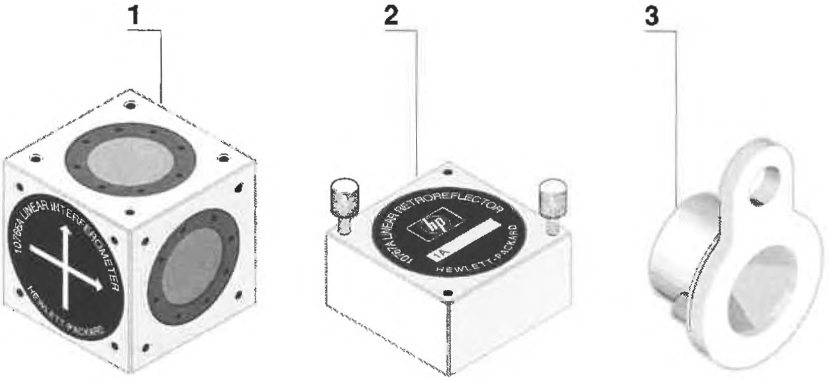
NOTE The HP 10769A Beam Steering Mirror cannot be used to make linear measurements with an HP 5526A calibrator because of the beam-spacing used in that system.

HP 10767B Lightweight Retroreflector

The HP 10767B Lightweight Retroreflector is intended for use as the measurement retroreflector in situations where the weight of the HP 10767A retroreflector might distort the machine—for instance, a small robot or a small coordinate measuring machine (CMM). The two retroreflectors use identical optical elements, the only difference is in their housings.

HP 10744A Accessory Kit

The HP 10744A Accessory Kit provides mounting hardware you can use with many Hewlett-Packard measurement optics to meet the physical needs of your measurement situation. For instance, with multiple posts and the large base, you can build a tall, rigid tower for mounting measurement optics high in the center of the machine's work zone.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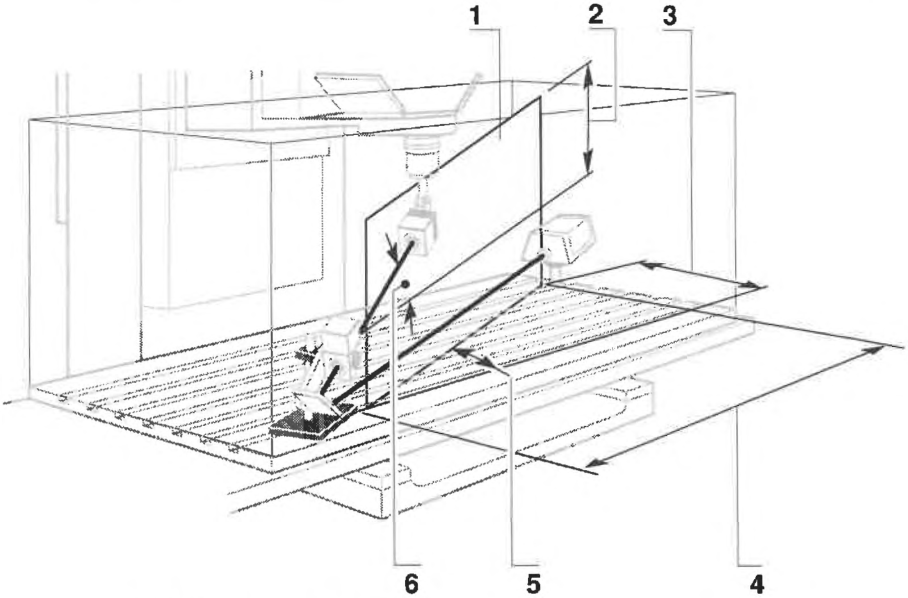
10766A LINEAR INTERFEROMETER
HEWLETT-PACKARD
10767A LINEAR RETROREFLECTOR
hp
1A
HEWLETT-PACKARD

1 HP 10766A Linear Interferometer
2 HP 10767A Linear Retroreflector
3 HP 10767B Lightweight Retroreflector

Figure 11–2. Typical Optics Used for Diagonal Measurements



1 Diagonal plane
2 Z-axis range of motion
3 Y-axis range of motion
4 X-axis range of motion
5 Azimuth angle (α)
6 Elevation angle (β)

Figure 11–3. Typical Diagonal Measurement Setup

Before you start

Previous experience in setting up and making non-diagonal linear measurements can help you learn to set up and make diagonal measurements.

Before you set up for diagonal measurements:

1. **Determine:**

   - the type of machine you are working on
   - which body diagonals or face diagonals will be measured. (See Figure 11–3.)

   Examples of machine types are

   - stacked-stage with vertical spindle—table moves in X and Y
   - single-slide table—column moves in Y and Z, table moves in X only.

2. **Calculate and record the angles required for setup:**

   - the azimuth angle (α) of the body diagonal planes on the XY plane (see Figure 11–3), and
   - the elevation angle (β) of the body diagonals, in the diagonal planes.

3. **Program the machine to traverse the four body diagonals to be measured.**

Calculating Angles

The azimuth angle (or face diagonal angle), α, (on the XY plane) of the diagonal plane containing the elevation diagonals is the angle whose tangent is (Y/X), where:

X is the length of the X-axis travel in the work zone being calibrated, and

Y is the length of the Y-axis travel in that zone

This angle may also be called arctangent Y/X: Arctangent is sometimes abbreviated arctan, ATAN, or $\tan^{-1}$.

Similarly, the elevation angle, β, of either of the body diagonals, with respect to the XY plane, is arctangent Z/D, where:

Z is the height of the work area being calibrated, and

D is the length of the diagonal projected onto the XY plane, $= (X^2 + Y^2)^{1/2}$

If you want to calculate it, the length of the body diagonal (B) is $(X^2 + Y^2 + Z^2)^{1/2}$.

There are many ways you can determine the angles involved, depending on the calculators or mathematical tables you have available and your expertise at using them. The example given below is presented in very brief terms. Calculations of this type are quite common; if you need more information about them, refer to other sources, such as calculator manuals, trigonometry books, and so forth.

In the example below, X=30, Y = 20, and Z = 15; the units of measurement do not matter, as long as they are all the same.

$\alpha = \arctan (Y/X) = \arctan 20/30 = 33.69$ degrees

$D = (X^2 + Y^2)^{1/2} = (900 + 400)^{1/2} = 36.055128$

$\beta = \arctan (Z/D) = \arctan 15/36.055128 = 22.59$ degrees

$B = (X^2 + Y^2 + Z^2)^{1/2} = (900 + 400 + 225)^{1/2} = 39.051248$

Placing and using the sensors

Sensor placement for Diagonal measurements is the same as that for HP 5529A calibrator Linear measurements. Refer to the Linear or Distance measurement chapter of your user documentation for information.

Assembling the interferometer, reference retroreflector and beam steering arm

1. **Determine the setup you want to use for your measurement. Refer to Table 11-1 and Figures 11-4 and 11-5, or to notes about previous setups, to determine the interferometer and reference retroreflector assembly arrangement you want to use. Different combinations provide different angle range capabilities. The measurement shown in Figure 11–3 is "far low to near high," on a stacked-stage, vertical-spindle machine, with the laser head at the right. (The symbol glossary at the end of this chapter describes the symbols used here and in other places in this chapter to indicate general configurations or interferometer configurations.)**

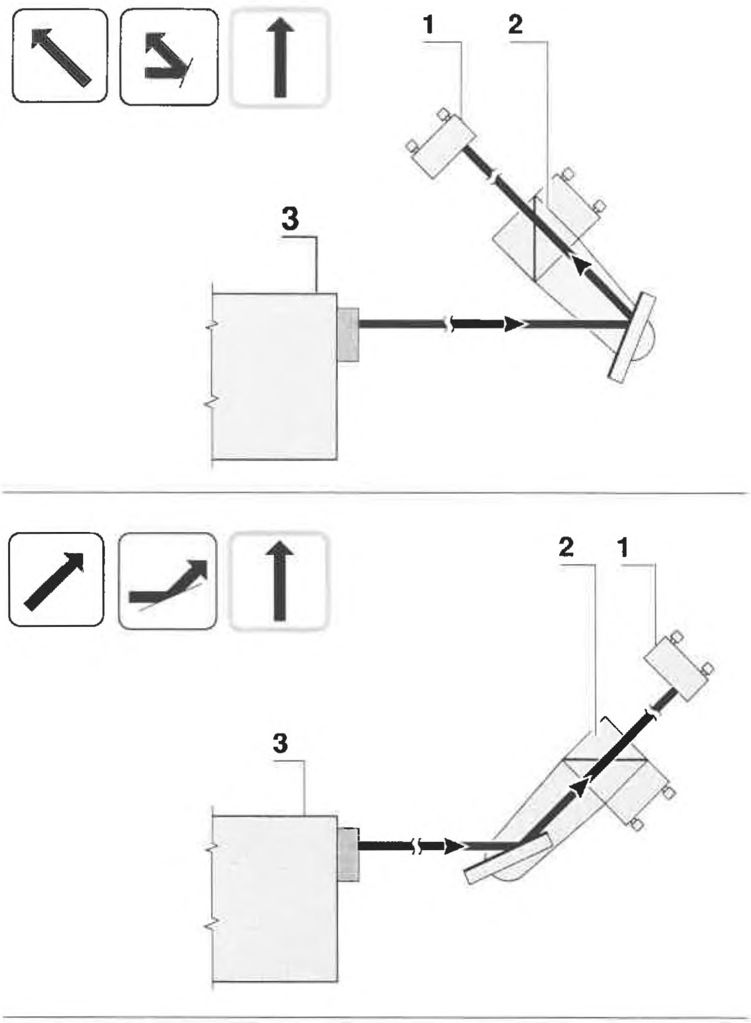
2. **Assemble the interferometer and reference retroreflector. In addition to the figures referenced above, you can refer to Figure 11–8 for help. Be sure the retroreflector is tightly fastened to the interferometer.**

3. **Attach the interferometer assembly you created in step 2 to the beam steering arm, keeping in mind the configuration you want for your measurement. See Figure 11–5.**

4. **Set this assembly in a safe place while you assemble other pieces of the diagonal measurement hardware.**

Table 11–1. General configurations—Laser Head at Left

Diagonal, Symbol, Measurement Type (for laser head at left)	**Elevation Angle Range** (degrees)	**Beam-steering mirror Configuration:** (see Figures 11-4, 11-5)	**Interferometer Configuration** (see Figures 11-5, 11-8)
Lower right to upper left ↖ Far low to near high	30–90	↘	Straight-through (↑)
	0–30	↗	Turned Left (↰)
	0–60	↘	*Turned Right (Inverted)* (↲)
Lower left to upper right ↗ Near low to far high	60–90	↗	Straight-through (↑)
	0–30	↗	*Turned Left (Inverted)* (↳)
	0–60	↘	Turned Right (↱)



1 Measurement retroreflector
2 Beam-steering arm with interferometer
3 Laser head

See Table 11-1 or 11-2 for explanation of symbols

Figure 11–4. General Configurations—Laser Head at Left

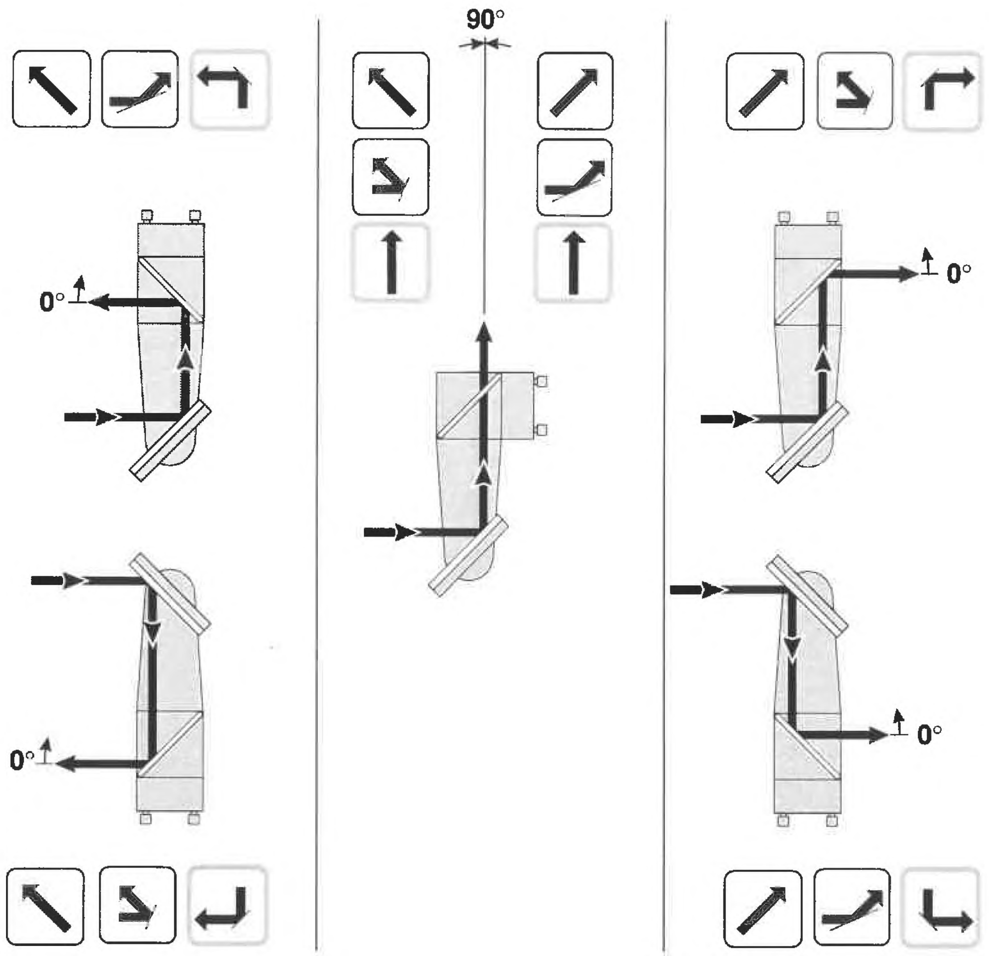


Figure 11–5. Beam Steering Configurations—Laser Head at Left

Assembling the Interferometer, Post, Base, and Clamp

If you are using the right-angle clamp in a post-and-base setup for mounting your interferometer (on the beam steering arm), align the clamp so its long edge is parallel to the edge of the base. This will make alignment of the interferometer to the XY diagonal of the measurement easier. Refer to Figure 11–6.

1. **Assemble and tighten the post(s) and base.**
2. **Slide the right-angle clamp onto the post. Do not tighten the clamp at this time.**
3. **Tip the assembly on its side on a flat surface so the long edge of the base and the long edge of the clamp are both resting flat on the surface. You may have to let the top of the post extend beyond the edge of the surface in order to be able to do this.**
4. **Position the clamp so it is about 11.5 cm (4.5 inches) above the base, then tighten the clamp to the post.**
5. **To reduce problems due to vibration and other causes, install the beam steering arm, with the interferometer attached, as close as possible to the right-angle clamp. Insert and clamp a post through the horizontal hole in the right-angle clamp, then fasten the beam-steering arm to it, using one M10 setscrew in the arm. At this time, tighten the setscrew just snugly, not tightly, so the arm can rotate about the post.**

   For greatest mounting stability, use only one setscrew to hold the arm to the post; this forces the post to the opposite side of the hole, providing three-point stability. The two setscrew holes are provided for improved flexibility and ease of use. For improved mounting stability, the hole for the post is not circular, but widened along the line of the setscrew holes; to see this, put a post in the hole. Using two setscrews—one in each hole—is likely to result in a less-stable setup, because the arm and post would have only two contact points instead of three, and the post could pivot around the axis of the setscrews.

A similar situation exists at the mirror-axle end of the arm. Again, use only one setscrew, in the hole that provides easiest access in your measurement setup. Tighten that setscrew enough to hold the mirror axle snugly, while still allowing the mirror to rotate.

6. **Set this assembly in a safe place while you assemble other pieces of the diagonal measurement hardware.**

- **1** Machine Table or surface plate
- **2** Base
- **3** Post
- **4** Post
- **5** Right-angle clamp

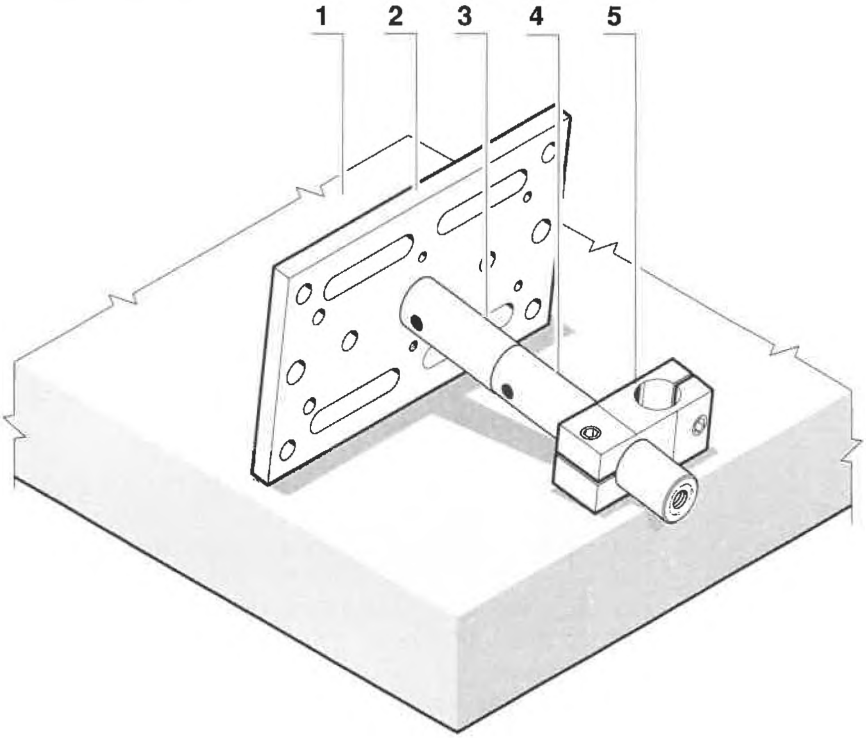


Figure 11–6. Aligning Right-angle Clamp with Edge of Base

Assembling the measurement retroreflector and ball-joint

Use the instructions below for the retroreflector you choose to use for your diagonal measurement. Refer to Figure 11–7 for these procedures.

HP 10767A Linear Retroreflector

1. **Remove any knurled-knob screw from the HP 10767A retroreflector.**
2. **Place the adapter plate over the back of the retroreflector so the countersunk holes are lined up with the retroreflector holes whose threads are most easily seen.**
3. **Use two M3×0.5×16 flathead screws to fasten the retroreflector to the adapter.**
4. **Screw the adapter plate onto one of the threaded ends of the ball-joint assembly. Tighten this connection securely, by hand.**
5. **Set this assembly in a safe place until you install it on the machine.**

HP 10767B Lightweight Retroreflector

1. **Fasten the HP 10767B retroreflector on the ball-joint, using an HP 10767-20203 Clamp Nut.**
2. **Set this assembly in a safe place until you install it on the machine.**

1	Adapter plate
2	Countersunk holes
3	Center hole—threaded M10
4	Threaded holes—M3
5	Ball-joint assembly
6	Flathead screw—M3×0.5×16
7	HP 10767A linear retroreflector
8	Laser beam from interferometer
9	Nodal point
10	HP 10767B lightweight retroreflector
11	Centerline of spindle axis
12	Clamp nut

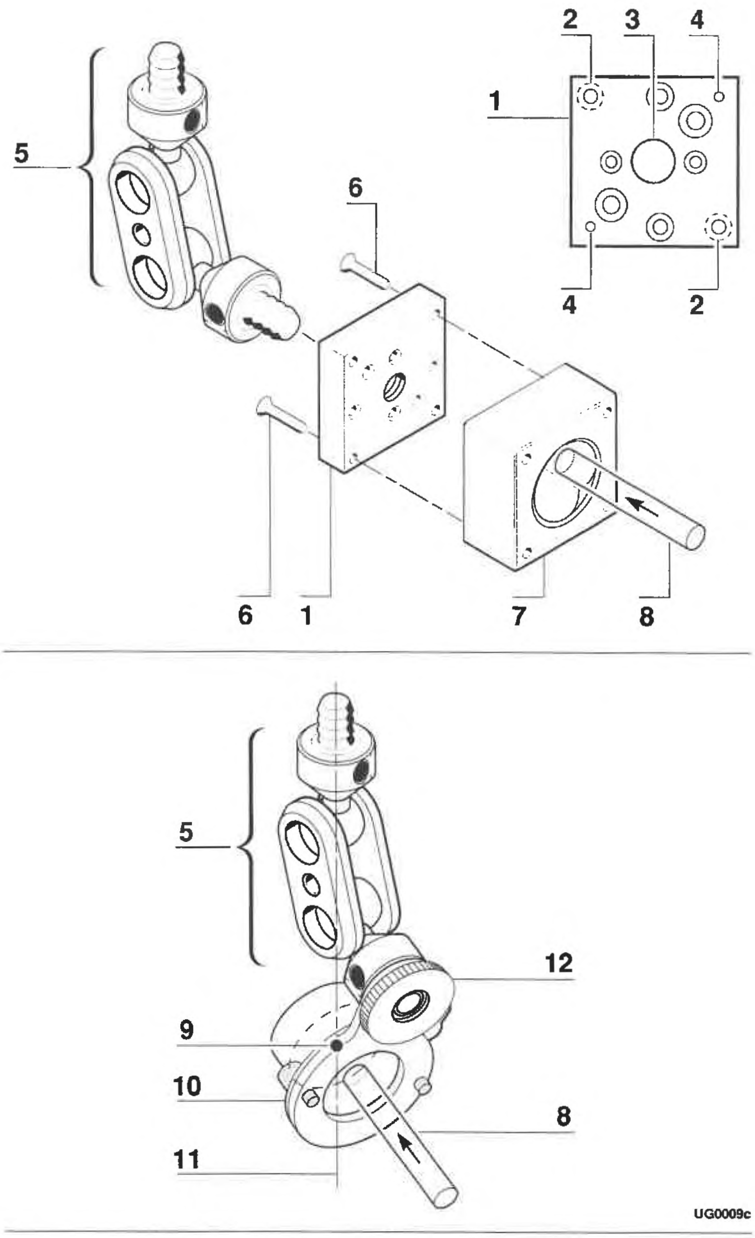


Figure 11–7. Assembling Measurement Retroreflector and Ball-joint

Installing and aligning the optics on the machine

All machines and measurement situations are not the same. Use the instructions here as a guide to help you in your specific application. Making notes and diagrams of how you set up the measurement hardware can help you or someone else make identical setups on the same machine or a similar one in the future, or can resolve any doubt about exactly what you did.

The procedure given here can be used for either "near low to far high" or "far low to near high" measurements. It aligns the laser measurement beam to the programmed path actually traversed by the machine, such as a body diagonal of the work zone volume. This technique allows you to save and reuse the machine control program for future calibrations. If you had to align the machine to the laser beam, you could not easily reuse the same program, and you could not repeat the same measurement; repeating the same measurement provides a valuable comparison for assessing changes in machine performance.

The general procedure has these major steps:

1. **Installing the measurement optics on the machine.**
2. **Installing and initially aligning the laser head.**
3. **Aligning the beam to the XY plane diagonal (azimuth angle, α) of the measurement.**
4. **Aligning the beam to the elevation angle (β) of the measurement.**

Installing the measurement optics on the machine

This procedure is for a stacked-stage milling machine; that is, one whose table can move in X and Y. Adapt the procedure as necessary when you want to use some other setup.

This procedure assumes that you have performed the assembly procedures earlier in this guide.

This procedure has these major steps:

1. **Mounting the interferometer assembly on the machine table.**
2. **Installing the measurement retroreflector.**

Mounting the interferometer assembly on the machine table

To mount the interferometer assembly on the machine, follow these steps:

1. **Determine where on the machine you want to mount the interferometer-and-base assembly. The location depends on the machine, the type of measurement, and the space around the machine.**
2. **Set the adjustable triangle to the azimuth (XY plane) angle for your measurement, calculated and recorded earlier.**
3. **Establish a suitable reference surface on your machine's table (such as a "T" slot) and place the adjustable triangle against it (see Figure 11–11). When setting up the reference surface, be sure to allow for any offset between the edge of the interferometer assembly base and the actual location of the diagonal plane.**

4. **Place the interferometer assembly in position on the table, against the edge of the adjustable triangle. The interferometer's exit face should be pointing along the XY-plane diagonal of your measurement.**

5. **Carefully clamp the interferometer assembly base to the machine table.**

6. **Set the adjustable triangle to the elevation angle of the body diagonal you are measuring.**

7. **Use the adjustable triangle to set the initial elevation angle of the interferometer assembly and beam steering arm (see Figure 11–12). For a coarser alignment, you can simply use the scale on the side of the beam steering arm assembly.**

8. **Set the adjustable triangle for 90 degrees.**

9. **Use the adjustable triangle against the table or the interferometer assembly base and the back of the beam steering mirror tray to set the beam steering mirror vertical.**

10. **Adjust the knob on the back of the beam steering mirror tray to set the mirror in its neutral position. The pointer on the knob should be in line with the mark on the tray.**

    You will refine these initial adjustments in the procedures below.

Installing the measurement retroreflector

The measurement retroreflector is a cube corner having the property of redirecting an input beam back toward its source along a parallel line. Exact orientation of the retroreflector is not critical. This procedure assumes that you have already assembled the measurement retroreflector and ball-joint as described earlier.

1. **If necessary, remove any tool in the spindle.**

2. **Insert the free end of the ball-joint assembly into the spindle and tighten it in place.**

3. **Point the measurement retroreflector's face toward the interferometer's measurement face, align the retroreflector so these faces are parallel, then tighten the ball-joint screw to hold this alignment.**

NOTE You can slightly reduce the sensitivity of the measurement retroreflector to rotational motions of the spindle by placing the retroreflector's nodal point on the spindle's axis. In either retroreflector described here, the nodal point is about 12.6 mm (0.5 inch) behind the front surface of the glass. (See Figure 11–7.)

Installing and initially aligning the laser head

Use this procedure to install the laser head on the tripod and perform the initial alignment of the laser beam to the XY plane face diagonal of the measurement and parallel to the XY plane (table) of the machine. This alignment is important during measurement as the table carrying the interferometer moves.

1. **Place the tripod at the desired point for your measurement. The vertical centerline of the tripod should be in or near the vertical plane containing the body diagonal you will be measuring. For this autoreflection alignment procedure, the longer the distance from the laser head to the interferometer, the more accurate the alignment can be; the ideal distance is from 1 to 4 meters (3 to 12 feet).**

2. **Set the laser head on the tripod and secure it. Refer to documentation for your laser head and tripod for details.**

3. **Connect the laser to its power source and turn it on.**

4. **Select the laser head's small output (upper) aperture, and the lower (return port) target, for alignment.**

5. **Adjust the laser head's and tripod's vertical and horizontal translation and pitch and yaw controls so the laser beam autoreflects from the beam steering mirror back to the laser head's output (upper) port.**

WARNING Never stare directly into the laser beam or any bright reflection of it. Failure to observe this warning may result in personal injury.

6. **Place the HP 10767-67001 alignment target (shown in Figure 11–1), with its hole up, over the front of the beam steering mirror. The front of the mirror tray has recesses that enable it to hold the target.**

7. **Adjust the tripod and laser head positioning controls so the beam autoreflects from the beam steering mirror back to the laser head's output (upper) port, through the hole in the target.**

8. **Remove the alignment target from the beam steering mirror.**

This completes the installation and initial alignment of the laser head.

Aligning the beam to the XY plane diagonal (azimuth angle, α) of the measurement

Use this procedure to improve laser beam alignment along the XY plane face diagonal.

In this procedure, you move a cube corner—in this case, the reference retroreflector attached to the interferometer—along the XY plane face diagonal and check for drifting of the return beam at the laser head.

To perform this procedure:

1. **Move the machine to place the interferometer assembly as close to the laser head as possible, without moving the laser head.**

NOTE Do not use the mirror tilt adjustment knob on the bottom of the mirror tray until instructed to do so.

2. **Rotate (pitch) the beam steering mirror so beam enters the interferometer perpendicular to its input face. The return beam from the reference retroreflector will produce a dot on the face of the laser head near the return (lower) port.**

NOTE An alternate procedure that may be easier here is to use a rubber band to hold a small gage block to the input face of the interferometer and use autoreflection back through the beam steering mirror to the laser head input port. Be sure to remove the gage block when done.

3. **Observe the return beam dot on the laser head's lower (return) port as you move the machine's table to increase the distance between interferometer and the laser head along the XY plane diagonal of the measurement. Continue moving the interferometer until you do not see the dot or until the end of travel is reached, whichever occurs first. If you lose sight of the dot before end of travel is reached, return the interferometer to the last position at which you saw the dot.**

   If the dot drifts as the interferometer moves, the laser beam is not perfectly aligned to the travel path. The remainder of this procedure corrects that alignment.

4. **With the interferometer at its farthest travel point or at the last point at which a return dot was visible, yaw and pitch (turn and tilt) the laser head on the tripod as necessary to center the return beam on the lower port. You may speed your alignment procedure by doing some overcorrection, moving the dot to the other side of the lower port; experience will help you here.**

5. **Observe the return beam spot on the laser head's face as you use the machine to move the interferometer toward the laser head.**

6. **If the return beam spot moves, translate the laser head horizontally and vertically, without turning it, so most or all of the return beam from the interferometer will enter the lower port. Do not overcorrect on your translation adjustments.**

7. **Repeat steps 3 through 7 until the return beam from the interferometer can enter the laser head's lower port at all interferometer positions along the XY plane diagonal.**

   Now your setup is ready for aligning to the actual measurement (body) diagonal. DO NOT MAKE ANY MORE CHANGES TO THE LASER HEAD OR TRIPOD POSITION CONTROLS UNTIL INSTRUCTED TO DO SO.

Aligning the beam to the elevation angle (β) of the measurement

This procedure assumes that you have performed the assembly, installation, and alignment procedures above. This means that the laser head has already been aligned to the XY diagonal (azimuth) path of your measurement, and you should only need to adjust the beam steering mirror to direct the beam toward the measurement retroreflector moving along the measurement diagonal.

It is likely that, no matter how precise you have tried to be in your setup, you will have to make some alignment adjustments. Here, previous experience performing distance (linear) alignments can be a help as you align the optics.

1. **Move the machine spindle and table to place the measurement retroreflector close to the output face of the interferometer.**

2. **Adjust the measurement retroreflector so its face is parallel to and centered on the interferometer's measurement face (the one facing along the measurement path).**

3. **At this time, the measurement retroreflector should be providing a return beam to the front of the laser head. If the return beams from the two retroreflectors overlap, you will see only one dot.**

NOTE You may have to reposition the measurement retroreflector slightly in order to overlap the measurement beam dot and reference beam dot on the laser head's input port.

NOTE If you want to see only the dot from the measurement path return beam, remove the reference retroreflector from the interferometer, being careful not to disturb the interferometer alignment. Be sure to replace this retroreflector before you try to make a measurement.

Another way to identify the measurement beam dot during alignment is to use your hand to momentarily interrupt the measurement path beam.

4. **Observe the measurement beam dot as you move the machine to increase the distance between the interferometer and the measurement retroreflector along the body diagonal.**

   Continue moving the interferometer and measurement retroreflector until the moving dot disappears or until the end of travel is reached, whichever occurs first. If the dot disappears before end of travel is reached, return the interferometer to the last position at which you saw the dot.

   Movement of the measurement beam dot indicates that the measurement beam was not perfectly aligned to the work zone body diagonal. If the dot moves, perform steps 5 through 9 below.

5. **Slightly rotate the beam steering mirror to move the measurement return dot back to the laser head's return port. You may also have to make a slight adjustment of the knob on the bottom of the mirror tray to do this.**

6. **Move the machine to return the measurement retroreflector and the interferometer to their close-together position.**

7. **If necessary, reposition the measurement retroreflector so its return dot overlaps the dot from the reference retroreflector attached to the interferometer. (If you removed the reference retroreflector earlier, you should re-attach it now.)**

8. **If necessary, slightly translate the laser head, without turning it, so the overlapping dots are over its lower (return) port.**

9. **Repeat steps 3 through 9 to verify satisfactory alignment, indicated by both dots remaining stationary on the laser head's return port as the measurement optics are moved through the entire measurement travel range.**

10. **When the alignment is satisfactory,**
    a. Tighten all adjustment locks to keep settings from changing.
    b. Repeat steps 3 through 8, to be sure nothing has changed.

Making your measurement

At its simplest, a diagonal measurement is a linear distance measurement along a line that is not necessarily parallel to nor perpendicular to one or more of the machine's major axes (X, Y, or Z). As such, a diagonal measurement is subject to the same accuracy problems as any other laser linear distance measurement. For more information about this, read the appropriate information in your measurement system documentation. In particular, see the discussion of cosine error.

In the absence of any special instructions, take and save your diagonal measurement data in the same way you take your linear distance measurement data.

Aligning for the second diagonal

Alignment to the “far low to near high” diagonal in this plane is similar to the procedure above for the first diagonal (“near low to far high”). However,

NOTE Do not move the laser head. The beam is already aligned for the second diagonal.

- The interferometer assembly is moved to the position on the table where it intersects the second diagonal; that is, the opposite end of the diagonal plane of the work zone being calibrated.

- The interferometer and beam steering mirror angles must be reset as required for the new measurement. Again, you can use the adjustable triangle to provide a more accurate initial setup. Refer to Figures 11-4 and 11-5 to determine what might be the best setup for your second-diagonal measurement.

- The measurement retroreflector must be reoriented, to return the measurement beam to the interferometer in its new location.

Basics

- The interferometer has three configurations (see Figure 11–8). Configurations are named for the direction in which the beam from the laser head is bent, when viewed as shown.
- Laser beams enter and leave the interferometer perpendicular to its faces.
- The beam steering assembly allows a range of (elevation) angles between the laser head and the interferometer (see Figure 11–9). The minimum angle is just before the corner of the interferometer clips the beam between the laser head and the steering mirror. The maximum angle is just before the mirror no longer reflects enough of the beam to enable a measurement. Note that the angles shown in Figure 11–9 are only those between the interferometer and the incoming laser beam; the measurement elevation angle can be anywhere from 0 to 90 degrees with respect to a horizontal plane, however no single interferometer configuration allows the beam to be used throughout this range (see Figures 11-4 and 11-5, and Table 11-1).
- Two beam paths are involved in the interferometer's measurement arm—the beam from the laser head and the beam returned to the receiver in the laser head.

  Whenever a measurement configuration (typically a “far low to near high” general configuration) directs the measurement path back toward the laser head, the relationship of the two beams is inverted from that normally occurring at the interferometer (see Figure 11–10). Keeping this in mind can help you understand and use alignment procedures.
- For procedures in this chapter, azimuth angles (angles on the XY (horizontal) plane) are measured with respect to the X-axis or a line parallel to it (see Figure 11–3 or 11–11).

- Elevation angles (measured in the vertical plane containing the diagonals) are measured with respect to the XY plane or a plane parallel to it. (See Figure 11–3 or 11–12.) The maximum elevation angle for any measurement type is 90 degrees. The minimum elevation angle is 0 degrees. When the elevation angle has crossed through either 90 or 0 degrees, the measurement type has changed; see Figure 11–4.
- When using the adjustable triangle for alignment, you can use secondary references as required. For example if the azimuth angle is less than 45 degrees, you can use the Y-axis as the reference. (See Figure 11–11.)
- In general, aligning the laser beam for a body diagonal measurement is the same as aligning the beam for any other linear (distance) measurement, except—you have one more optical element, and the diagonal path doesn't provide a reference surface that allows you to use true square for initial alignment before placing the measurement optics. Thus, you must move the optics on the machine along the diagonal path to achieve final alignment.
- A pair of body diagonals is contained in a single vertical plane. The four body diagonals are contained in a pair of intersecting vertical planes.
- The laser beam must be aligned in the vertical plane containing the body diagonal(s) you are measuring.
- The interferometer and beam steering assembly may be at either end of a diagonal path.
- The laser head may be to the left or right of the interferometer, when viewed from the side.
- Measurements and measurement setups in this chapter are identified in terms of the end points of the diagonal involved. The first term identifies the interferometer's position, the second term identifies the measurement retroreflector's position at the opposite end of the diagonal. "Near" and "far," refer to end points of the body diagonals in relation to the laser head's physical position. "Low" and "high" refer to the end points of a body diagonal in relation to each other.

1 Laser beam to measurement retroreflector
2 HP 10767A linear retroreflector
3 HP 10766A linear interferometer
4 Laser beam from laser head

See Table 11-1 or 11-2 for explanation of symbols.

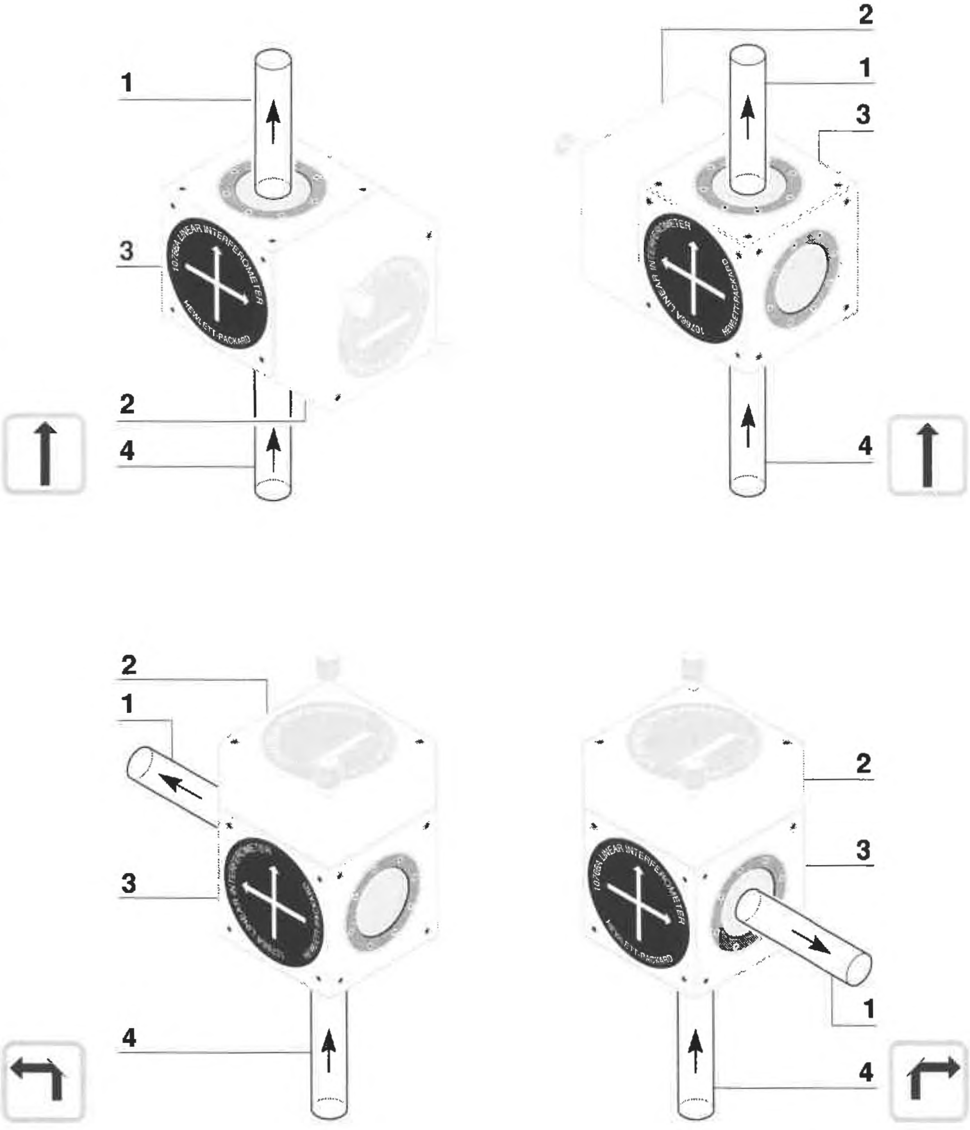

1
3
2
4
10766A LINEAR INTERFEROMETER
HEWLETT-PACKARD
2
1
3
4
2
1
3
4
2
3
1
4

Figure 11–8. Interferometer Configurations

1 HP 10766A linear interferometer
2 Beam-steering arm
3 Beam steering mirror
4 Beam from laser head
5 Beam to interferometer
6 Angle between beams—
30 ° minimum,
120 ° maximum

See Table 11-1 or 11-2 for explanation of symbols.

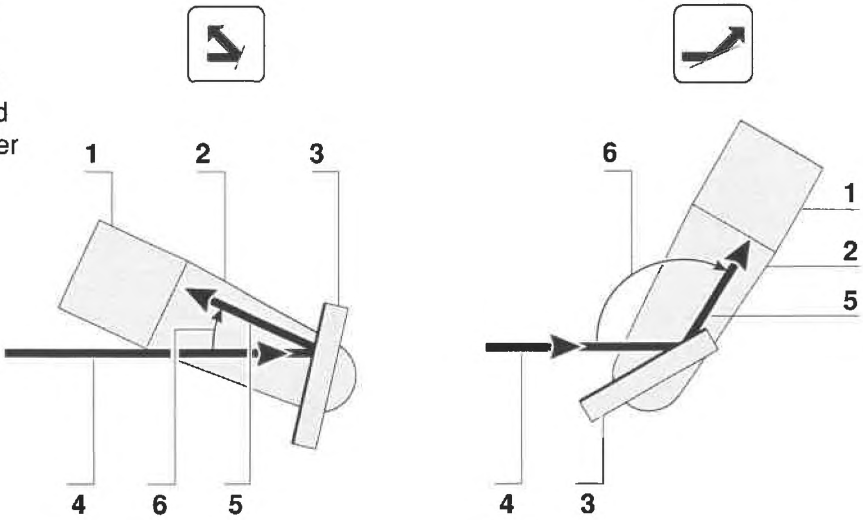


Figure 11–9. Beam Steering Angle Ranges

1 Measurement retroreflector
2 Return beam to laser head
3 Outgoing beam from laser head
4 Beam-steering arm assembly with interferometer
5 Laser head

See Table 11-1 or 11-2 for explanation of symbols.

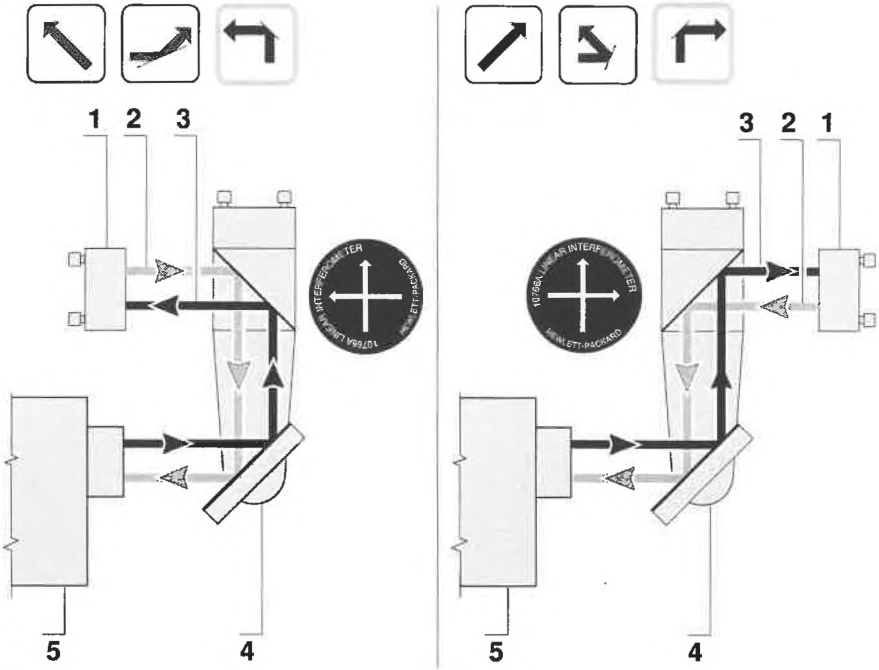

1
2
3
5
4
10766A LINEAR INTERFEROMETER
HEWLETT-PACKARD
3
2
1
5
4

Figure 11–10. Two Beams

1 Laser beam along diagonal plane
2 Machine table top
3 Base
4 Y-axis or parallel line on machine table top
5 Laser Head
6 Adjustable triangle
7 X-axis or parallel line on machine table top

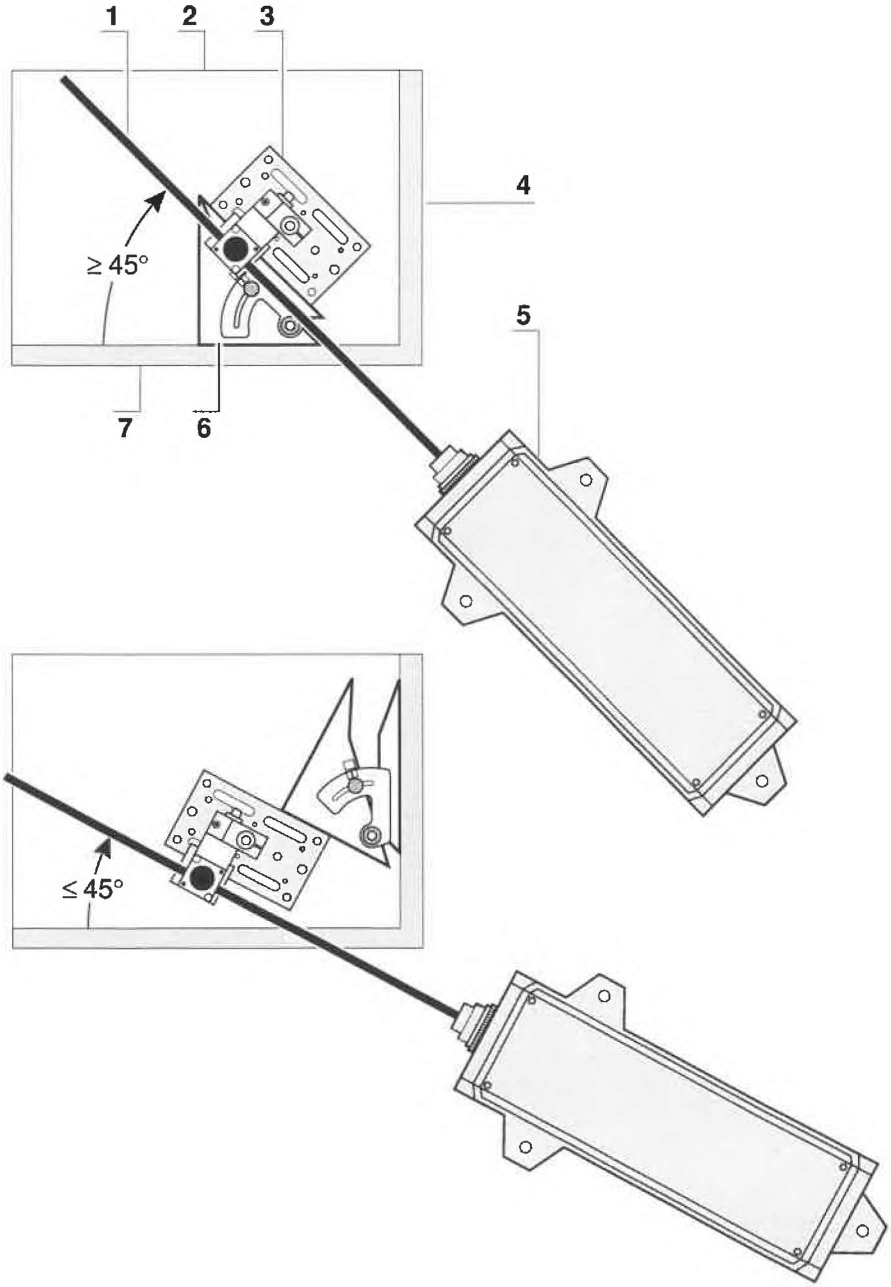


Figure 11–11. Setting the XY Plane Diagonal Angle Using the Adjustable Triangle

1 Adjustable triangle
2 Beam steering assembly with interferometer and reference retroreflector
3 Beam to measurement retroreflector
4 Elevation angle between horizontal plane and beam
5 Horizontal reference plane
6 Beam from laser head

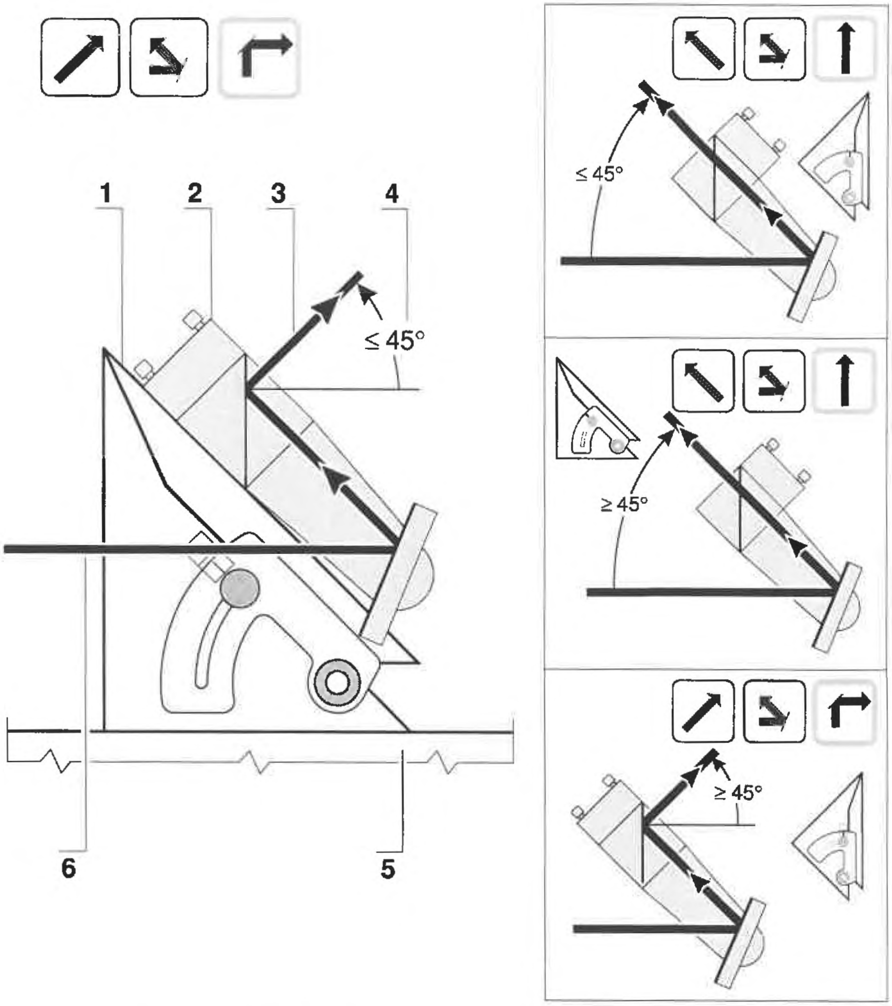


Figure 11–12. Setting the Elevation Angle Using the Adjustable Triangle

Characteristics

HP 10768A Diagonal Measurement Kit and HP 10769A Beam-steering Mirror

Weight:

10768-60201	Beam steering assembly: 354 g (12.5 oz)
10768-20207	Right angle clamp: 68 g (2.4 oz)
10768-60203	Ball-joint assembly: 123 g (4.3 oz)
10768-20215	Adapter plate: 36 g (1.3 oz)
10785-20005	Post–long: 228 g (8.0 oz)
10776-20008	Post–medium: 111 g (3.9 oz)
10768-20213	Post–stub: 42 g (1.5 oz)
10767-67001	Alignment Target: 11 g (0.39 oz)
10768-20214	Base–large: 832 g (29.3 oz)
HP 10767B	Lightweight retroreflector: 34.7 g (1.2 oz)
10767-20203	Clamp Nut (used with HP 10767B retroreflector): 4.6 g (0.16 oz)

Mirror: Coating: Hard dielectric
Clear aperture: central oval 25 mm × 45 mm (1.0 × 1.8 in)
Flatness: 1/10 wavelength at 633 nm
Reflectance: ≥ 90% over incidence range of 0 ° to 60 ° at 633 nm (both s and p polarizations)

Adjustable Ball-joint threads: M10×1.5, M8×1.25

Modes of use:

1. Linear interferometer attached to Beam-steering arm assembly for diagonal measurements.
2. Linear interferometer mounted remotely from Beam-steering arm assembly for diagonal measurements.
3. Linear interferometer attached to Beam-steering arm for slant-bed lathe calibration.
4. Beam-steering arm alone as Beam-steering mirror.

Symbol Glossary

Throughout this chapter, symbols are used to help you visualize the general and interferometer configurations being shown or described. These symbols are defined below.

Table 11–2. Symbol Glossary

Symbol	Definition or Description	Examples
↖	Diagonal, lower-right to upper-left	Table 11-1, Figure 11-4, 11-5, 11-10, 11-12
↗	Diagonal, lower-left to upper-right	Table 11-1, Figure 11-3, 11-4, 11-5, 11-10, 11-12
↘ ↙	Beam steering mirror Configuration— Angles 90 degrees or less, Laser Left and Laser Right	Table 11-1, Figure 11-3, 11-4, 11-5, 11-9, 11-10, 11-12
↗ ↖	Beam steering mirror Configuration— Angles 90 degrees or more, Laser Left and Laser Right	Table 11-1, Figure 11-4, 11-5, 11-9, 11-10, 11-12
↑	Interferometer Configuration— Straight-through	Table 11-1, Figure 11-3, 11-4, 11-5, 11-8, 11-12
↰	Interferometer Configuration— Turned left	Table 11-1, Figure 11-5, 11-8, 11-10
↱	Interferometer Configuration— Turned right	Table 11-1, Figure 11-5, 11-8, 11-10, 11-12
↳	Interferometer Configuration— Turned left, inverted	Table 11-1, Figure 11-5
↲	Interferometer Configuration— Turned right, inverted	Table 11-1, Figure 11-5

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11. Diagonal measurements

11. Diagonal measurements

11

Diagonal measurements

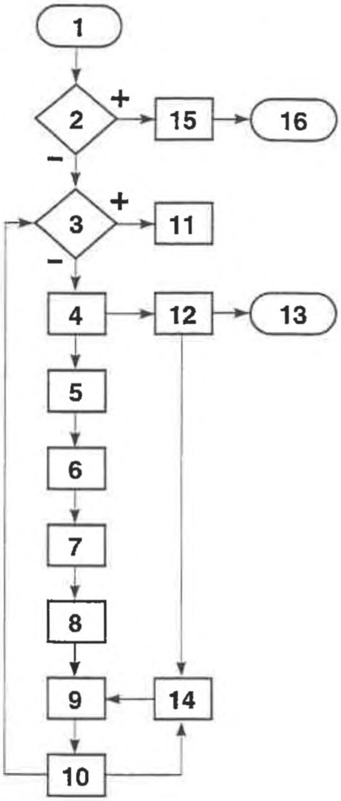
Diagonal measurements

This chapter explains how to make diagonal measurements, used for volumetric analysis, as described in ANSI standard B5.54. It also describes how to set up the measurement optics to make measurements on a slant-bed lathe.

Before performing the procedures described in this chapter, you must fully understand and know how to perform the procedures presented in the *HP 5529A Getting Started Guide*.

The Diagonal Measurement procedure differs from other HP 5529A calibrator measurement procedures in that it does not proceed along a single path from Set-Up Laser to Analyze Data. The data required for a Diagonal Measurement consists of the data from four linear measurements, each made along a body diagonal of the workspace you want to evaluate. If you already have existing data you want to analyze, you can simply recall it, using the Recall Data button on the Main Menu. If you need to acquire data for analysis, the preferred path is to start with the Diagonal Measurement's Set Up Laser menu and then proceed along the Set Up Measurement-Collect Data-Analyze Data path; note that this process must be performed for each diagonal axis whose data you need.

To help visualize the major steps in making a Diagonal Measurement, refer to the flowchart in Figure 11–1.



+ = yes

− = no
****

1 Start
2 Slant-bed lathe?
3 Do you have four axes of data for analysis?
4 Assemble and install measurement optics
5 Main menu, Select Other Meas, Select Diagonal to go, to Set Up Laser window
6 Install and align optics
7 Select Set Up Meas to go to Set Up Measurement window
8 Select Collect Data
9 Collect Data
10 Analyze Data Window (for single axis of data)

15 Set up optics as described under "Slant-bed lathe" in this chapter
16 Alternate end
****

11 Main menu
Select Recall Data
Select Recall Diagonal
Specify four .lin files
Select Setup & Data
12 Analyze Data window (with four axes of data)
13 Normal end
14 Previous button (on Analyze Data window:DIAGONAL measurement optics

Figure 11–1. HP 5529A Diagonal Measurements—Flowchart

Background—Why Diagonal Measurements?

The goal in calibrating a machine tool or coordinate measuring machine (CMM) is to determine its volumetric accuracy—that is, its ability to position accurately anywhere in the work zone. This cannot be done directly, but can be inferred by measuring the six degrees of freedom for each axis and the squareness of X, Y, and Z to each other. This can be a time-consuming process, and in many cases the time spent is not justified.

Thus, there is a need for a quick assessment of volumetric performance.

Measurement of work zone diagonals provides just such an assessment. As the spindle is traversed along a body diagonal of the work zone, all axes must move in concert in order to position accurately along the line. Diagonal measurements are useful in machine tool acceptance testing or in a periodic maintenance program to quickly assess the condition of a machine.

HP 10768A Diagonal Measurement Kit

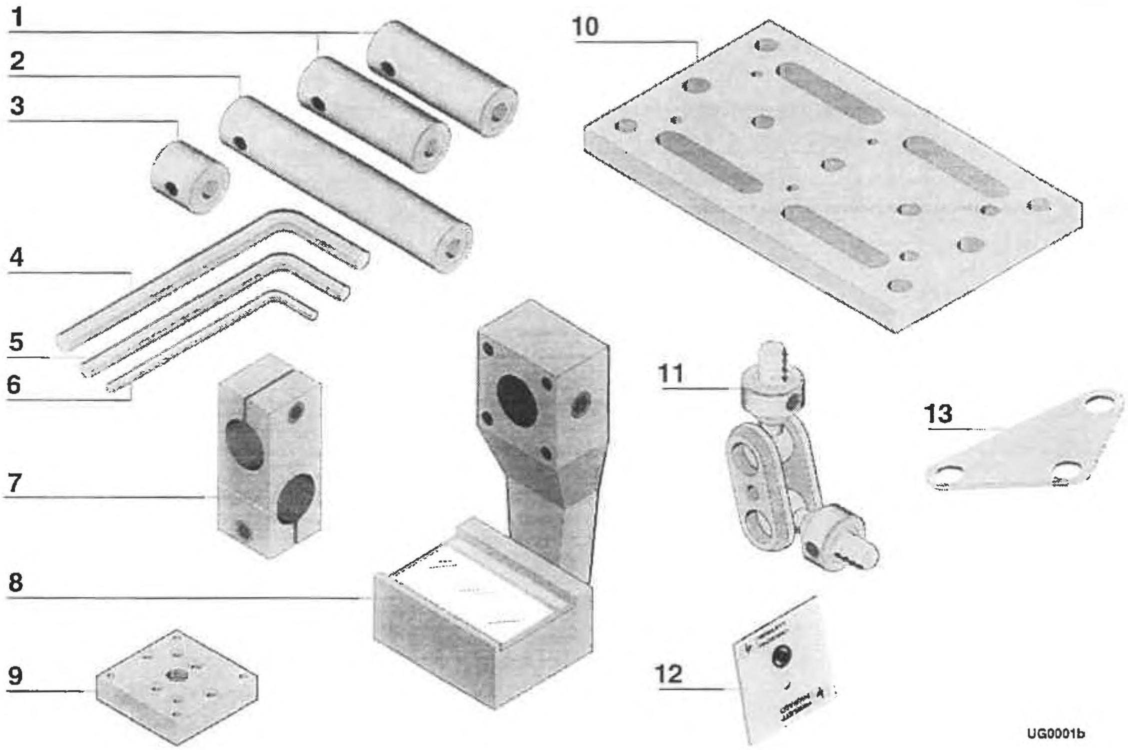
The HP 10768A Diagonal Measurement Kit is an optical accessory to the HP 5529A Dynamic Calibrator. It enables precise alignment of the laser beam to the body diagonals of the work zone of a milling machine or CMM. It also simplifies calibration of slant-bed lathes. The optics can be repeatedly aligned to the same machine diagonals at future calibrations. The HP 10768A enables implementation of ANSI/ASME standards B89 and B.5 for CMMs and machine tools, respectively.

The HP 10768A Diagonal Measurement Kit provides hardware that allows you to use Hewlett-Packard linear measurement optics (see Figure 11–3) in an HP 5529A Dynamic Calibrator to make distance measurements along any linear machine travel path.

A diagonal measurement is a linear displacement measurement along a line that is not necessarily parallel to nor perpendicular to one or more of the orthogonal major axes (X, Y, and Z) of the machine being calibrated. A typical diagonal measurement path is the body diagonal of a work zone (see Figure 11–4). A typical use for a diagonal measurement is to assess the volumetric performance of a machine tool or coordinate measuring machine. See ANSI/ASME Standard B5.54 for additional information about assessing volumetric performance using diagonal measurements.

The HP 10768A kit can also be used to simplify the calibration of a slant-bed lathe, as described under the "HP 10769A ..." heading below.

Much of the basic information you should know in order to perform a diagonal measurement is contained in the Linear Measurements chapter of your *HP 5529A Measurements Reference Guide*.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UG0001b

Figure 11–2. HP 10768A Diagonal Measurement Kit (Part 1 of 2)

Reference Number	Description	HP Part Number	Quantity in HP 10768A	Quantity in HP 10769A	Quantity in HP 10744A
1	post-medium	10776-20008	2	0	2
2	post-long	10785-20005	1	1	5 (Option 005 adds 5)
3	post-stub	10768-20213	1	0	2
4	hex key 5 mm	8710-2040	1	1	1
5	hex key 4 mm	8710-2041	1	1	1
6	hex key 2.5 mm	8710-1181	1	1	1
7	right-angle clamp	10768-20207	2	0	3
8	beam-steering assembly	10768-60201	1	1	0
9	adapter plate	10768-20215	2	0	1
10	base-large	10768-20214	1	1	1
11	flexible ball-joint assembly	10768-60203	1	0	1
12	alignment target	10767-67001	1	1	0
13	gusset	10744-00001	0	0	3
not shown	lens tissue	9281-0363	1 pkg	1 pkg	1 pkg
not shown	adjustable triangle	9300-1730	1	0	0
not shown	setscrew–brass tip, M10×1.5	0515-2336	1	1	0
not shown	setscrew–brass tip, M5×0.8	0515-2358	1	1	0
not shown	cap screw-socket-head-M3×25 long	0515-2359	4	4	4
not shown	setscrew M10×20	0515-2362	1	0	3
not shown	flathead screw-M3×0.5×16 long	0515-0078	4	0	2

Figure 11–2. HP 10768A Diagonal Measurement Kit (Part 2 of 2)

HP 10769A Beam Steering Mirror

The HP 10769A Beam Steering Mirror provides the beam-steering hardware from the HP 10768A kit, along with some mounting hardware. This combination of parts allows you to deflect a laser beam at any angle, in either the vertical or the horizontal polarization plane of the beam. One use of this hardware is for laser measurements and calibration of slant-bed lathes. In this case, the beam steering mirror is used to deflect the beam from the laser head upward, through the interferometer, along the lathe's cross slide; the other measurement optics and hardware can be the same as for standard measurements.

You can use one or more HP 10769A mirrors to create a path from the laser head to an interferometer in an otherwise inaccessible position. A typical use is with the HP 10768A Diagonal Measurement Kit on a milling machine in which the table moves in only one axis.

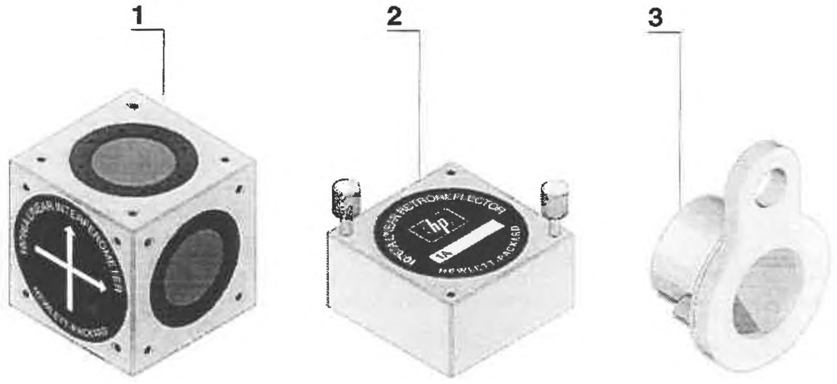
The HP 10769-C01, -C02, and -C03 are special mirror options which simplify, increase the flexibility or both, of the beam steering optics.

HP 10767B Lightweight Retroreflector

The HP 10767B Lightweight Retroreflector is intended for use as the measurement retroreflector in situations where the weight of the HP 10767A retroreflector might distort the machine—for instance, a small robot or a small coordinate measuring machine (CMM). The two retroreflectors use identical optical elements, the only difference is in their housings.

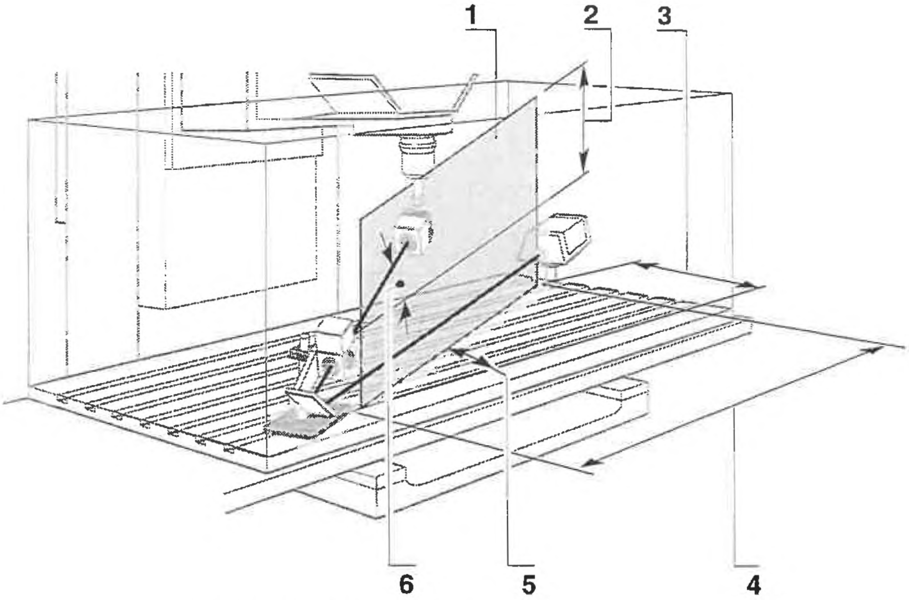
HP 10744A Accessory Kit

The HP 10744A Accessory Kit provides mounting hardware you can use with many Hewlett-Packard measurement optics to meet the physical needs of your measurement situation. For instance, with multiple posts and the large base, you can build a tall, rigid tower for mounting measurement optics high in the center of the machine's work zone.



1 HP 10766A Linear Interferometer
2 HP 10767A Linear Retroreflector
3 HP 10767B Lightweight Retroreflector

Figure 11–3. Typical Optics Used for Diagonal Measurements



1 Diagonal plane	**4** X-axis range of motion
2 Z-axis range of motion	**5** Azimuth angle (α)
3 Y-axis range of motion	**6** Elevation angle (β)

Figure 11–4. Typical Diagonal Measurement Setup

Setting up for the measurement

Guide: This information relates to flowchart item **4**.

Previous experience in setting up and making non-diagonal linear measurements can help you learn to set up and make diagonal measurements.

If you have not already done so, perform the following setup procedures before using the rest of the instructions in this chapter to make a diagonal measurement. Refer to the *HP 5529A Getting Started Guide* for complete instructions on performing these steps.

1 **Mount the laser head on the tripod and place the tripod near the target machine.**

2 **Connect the laser head and remote control unit to the appropriate ports on the computer**

The connectors are either on the rear or on the side of the computer.

Before you set up for diagonal measurements:

1 **Determine:**

- the type of machine you are working on
- which body diagonals or face diagonals will be measured. (See Figure 11–4.)

Examples of machine types are

- stacked-stage with vertical spindle—table moves in X and Y
- single-slide table—column moves in Y and Z, table moves in X only.

2 **Use the HP 5529A calibrator's Set Up Laser window to calculate the angles required for setup:**

- the azimuth angle (α) of the body diagonal planes on the XY plane (see Figure 11–4), and
- the elevation angle (β) of the body diagonals, in the diagonal planes.

3 **Program the machine to traverse the four body diagonals to be measured.**

Calculating Angles

The HP 5529A calibrator's diagonal measurement software calculates the azimuth and elevation angles for you, as you enter the dimensions of the workspace to be analyzed.

Placing and using the sensors

Sensor placement for Diagonal measurements is the same as that for HP 5529A calibrator Linear measurements. Refer to the *HP 5529A Measurements Reference Guide* “Linear measurements” chapter for information.

Assembling the interferometer, reference retroreflector and beam steering arm

1. Determine the setup you want to use for your measurement. Refer to Table 11–1 and Figures 11–5 through 11–7, or to notes about previous setups, to determine the interferometer and reference retroreflector assembly arrangement you want to use. Different combinations provide different angle range capabilities. The measurement shown in Figure 11–4 is "far low to near high," on a stacked-stage, vertical-spindle machine, with the laser head at the right. (The symbol glossary at the end of this chapter describes the symbols used here and in other places in this chapter to indicate general configurations or interferometer configurations.)

2. Assemble the interferometer and reference retroreflector. In addition to the figures referenced above, you can refer to Figure 11–21 for help. Be sure the retroreflector is tightly fastened to the interferometer.

3. Attach the interferometer assembly you created in step 2 to the beam steering arm, keeping in mind the configuration you want for your measurement. See Figures 11–5 through 11–7.

4. Set this assembly in a safe place while you assemble other pieces of the diagonal measurement hardware.

Table 11–1. General configurations—Laser Head at Left

Diagonal, Symbol, Measurement Type (for laser head at left)	**Elevation Angle Range** (degrees)	**Beam-steering mirror Configuration** (see Figures 11-5 through 11-7)	**Interferometer Configuration** (see Figures 11-5 through 11-7, and 11-21)
Lower right to upper left ↖ Far low to near high	30–90	↘	Straight-through (↑)
	0–30	↗	Turned Left (↰)
	0–60	↘	*Turned Right (Inverted)* (↵)
Lower left to upper right ↗ Near low to far high	60–90	↗	Straight-through (↑)
	0–30	↗	*Turned Left (Inverted)* (↳)
	0–60	↘	Turned Right (↱)

1	Measurement retroreflector
2	Measurement retroreflector (alternate position)
3	Elevation angle range: 30 to 90 degrees
4	Elevation angle range: 0 to 60 degrees
5	Linear interferometer
6	Beam-steering arm with interferometer
7	Laser head on tripod
8	Machine table

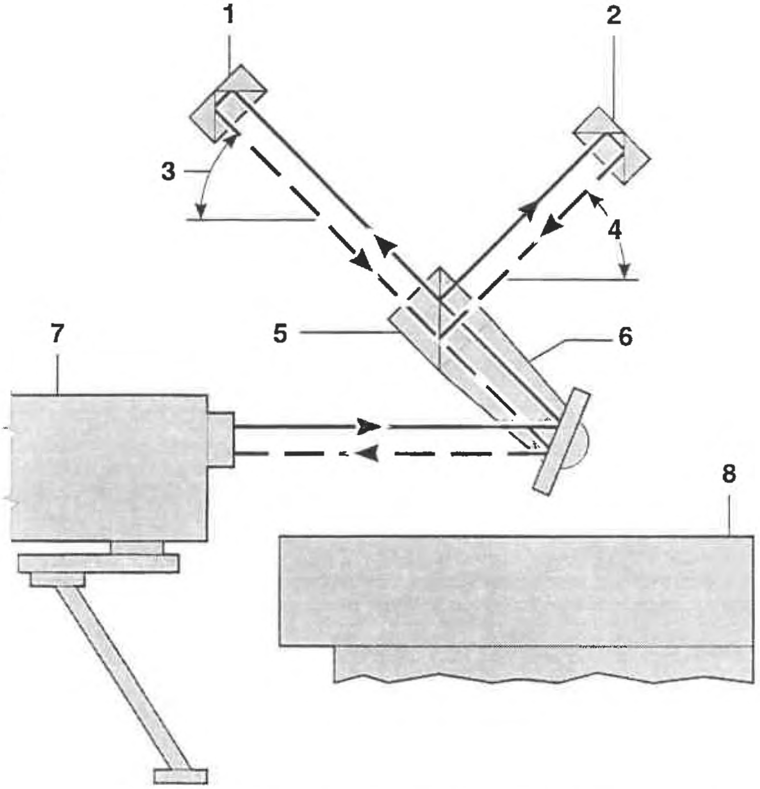


Figure 11–5. Diagonal Measurement Optics—Configuration 1

1 Measurement retroreflector
2 Measurement retroreflector (alternate position)
3 Elevation angle range: 30 to 90 degrees
4 Elevation angle range: 0 to 60 degrees
5 Linear interferometer
6 Beam-steering arm with interferometer
7 Laser head on tripod
8 Machine table

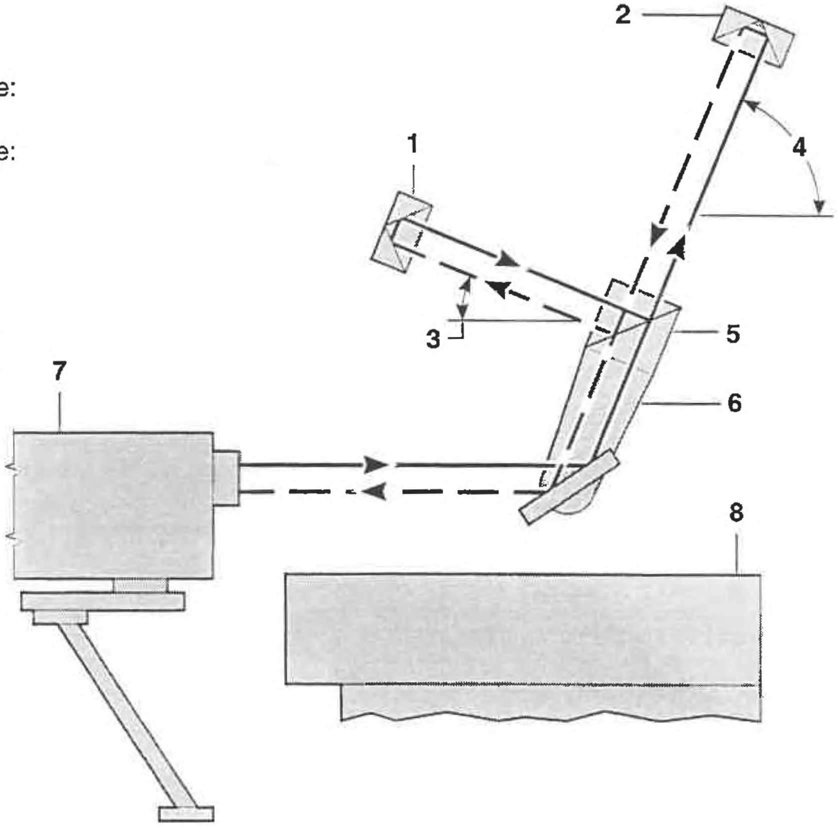


Figure 11–6. Diagonal Measurement Optics—Configuration 2

1	Measurement retroreflector
2	Elevation angle range: 0 to 60 degrees
3	Linear interferometer
4	Beam-steering arm with interferometer
5	Laser head on tripod
6	Machine table

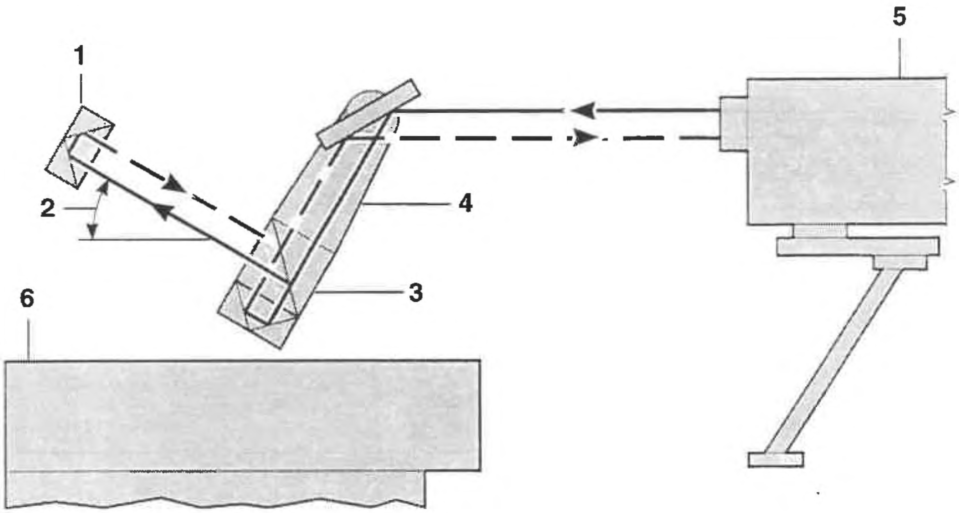


Figure 11–7. Diagonal Measurement Optics—Close-to-the Table Configuration

Assembling the Interferometer, Post, Base, and Clamp

If you are using the right-angle clamp in a post-and-base setup for mounting your interferometer (on the beam steering arm), align the clamp so its long edge is parallel to the edge of the base. This will make alignment of the interferometer to the XY diagonal of the measurement easier. Refer to Figure 11–8.

1. **Assemble and tighten the post(s) and base.**

2. **Slide the right-angle clamp onto the post. Do not tighten the clamp at this time.**

3. **Tip the assembly on its side on a flat surface so the long edge of the base and the long edge of the clamp are both resting flatly on the surface. You may have to let the top of the post extend beyond the edge of the surface in order to be able to do this.**

4. **Position the clamp so it is about 11.5 cm (4.5 inches) above the base, then tighten the clamp to the post.**

5. **To reduce problems due to vibration and other causes, install the beam steering arm, with the interferometer attached, as close as possible to the right-angle clamp. Insert and clamp a post through the horizontal hole in the right-angle clamp, then fasten the beam-steering arm to it, using one M10 setscrew in the arm. At this time, tighten the setscrew just snugly, not tightly, so the arm can rotate about the post.**

   For greatest mounting stability, use only one setscrew to hold the arm to the post; this forces the post to the opposite side of the hole, providing three-point stability. The two setscrew holes are provided for improved flexibility and ease of use. For improved mounting stability, the hole for the post is not circular, but widened along the line of the setscrew holes; to see this, put a post in the hole. Using two setscrews—one in each hole—is likely to result in a less-stable setup, because the arm and post would have only two contact points instead of three, and the post could pivot around the axis of the setscrews.

A similar situation exists at the mirror-axle end of the arm. Again, use only one setscrew, in the hole that provides easiest access in your measurement setup. Tighten that setscrew enough to hold the mirror axle snugly, while still allowing the mirror to rotate.

6 **Set this assembly in a safe place while you assemble other pieces of the diagonal measurement hardware.**

1	Machine Table or surface plate
2	Base
3	Post
4	Post
5	Right-angle clamp

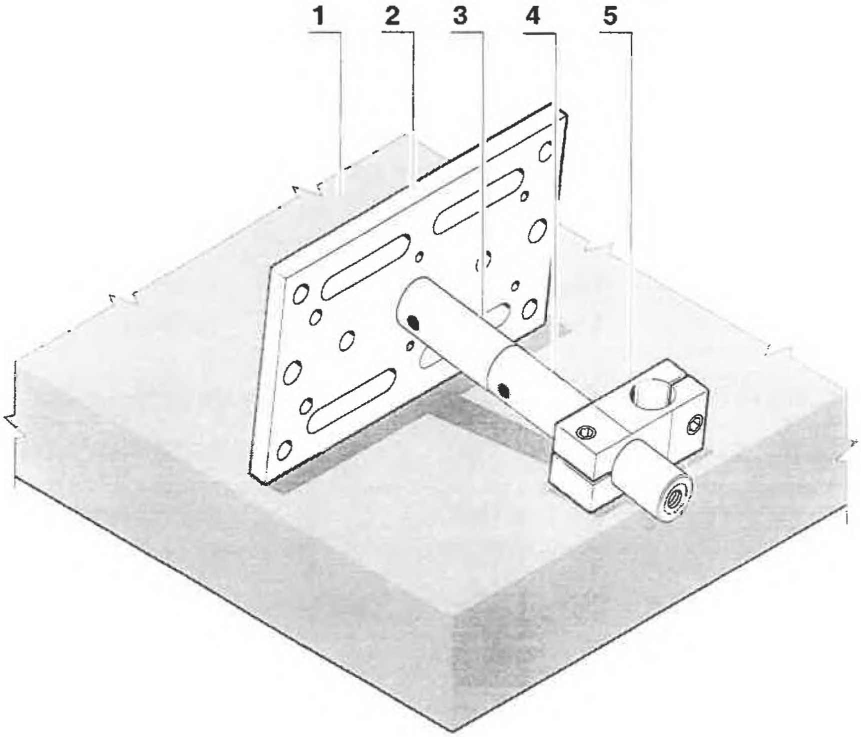


Figure 11–8. Aligning Right-angle Clamp with Edge of Base

Assembling the measurement retroreflector and ball-joint

Use the instructions below for the retroreflector you choose to use for your diagonal measurement. Refer to Figure 11–9 for these procedures.

HP 10767A Linear Retroreflector

1. **Remove any knurled-knob screw from the HP 10767A retroreflector.**
2. **Place the adapter plate over the back of the retroreflector so the countersunk holes are lined up with the retroreflector holes whose threads are most easily seen.**
3. **Use two M3×0.5×16 flathead screws to fasten the retroreflector to the adapter.**
4. **Screw the adapter plate onto one of the threaded ends of the ball-joint assembly. Tighten this connection securely, by hand.**
5. **Set this assembly in a safe place until you install it on the machine.**

HP 10767B Lightweight Retroreflector

1. **Fasten the HP 10767B retroreflector on the ball-joint, using an HP 10767-20203 Clamp Nut.**
2. **Set this assembly in a safe place until you install it on the machine.**

1 Adapter plate
2 Countersunk holes
3 Center hole—threaded M10
4 Threaded holes—M3
5 Ball-joint assembly
6 Flathead screw—M3x0.5x16
7 HP 10767A linear retroreflector
8 Laser beam from interferometer
9 Nodal point
10 HP 10767B lightweight retroreflector
11 Centerline of spindle axis
12 Clamp nut

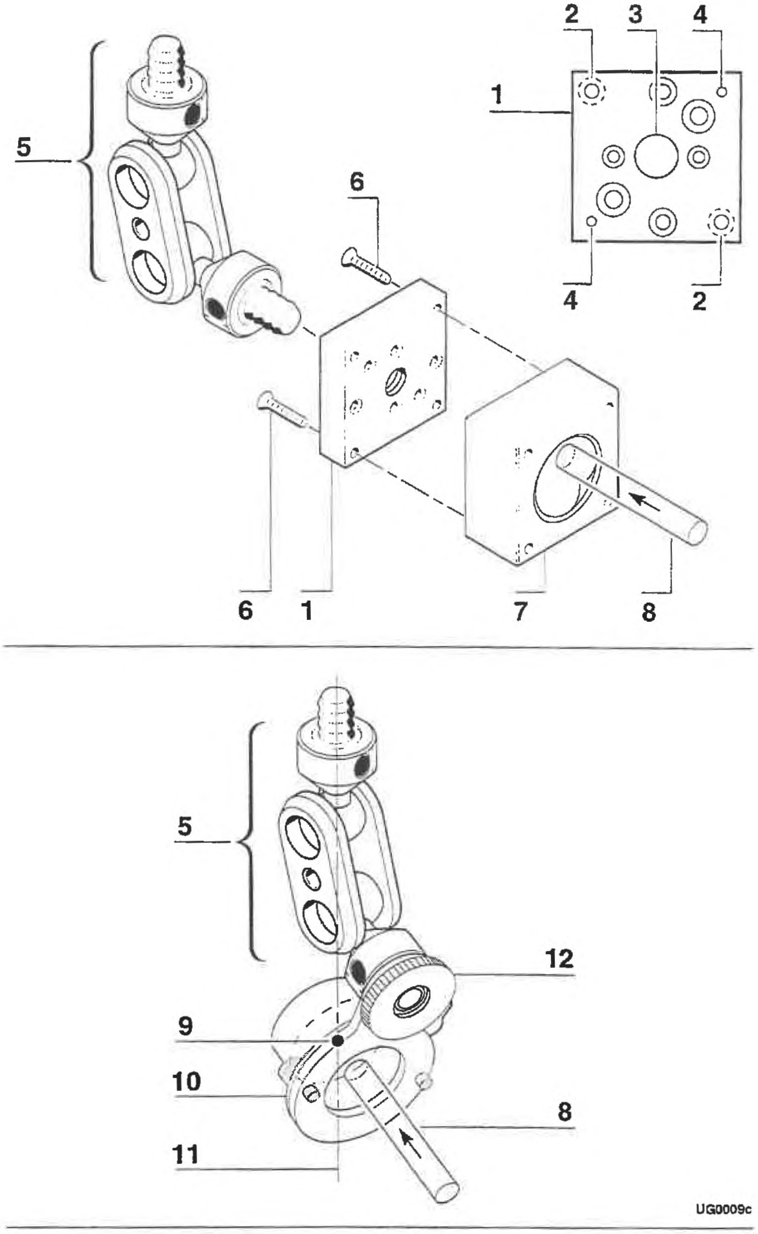


Figure 11–9. Assembling Measurement Retroreflector and Ball-joint

Installing and aligning the optics on the machine

All machines and measurement situations are not the same. Use the instructions here as a guide to help you in your specific application. Making notes and diagrams of how you set up the measurement hardware can help you or someone else make identical setups on the same machine or a similar one in the future, or can resolve any doubt about exactly what you did.

The procedure given here can be used for either "near low to far high" or "far low to near high" measurements. It aligns the laser measurement beam to the programmed path actually traversed by the machine, such as a body diagonal of the work zone volume. This technique allows you to save and reuse the machine control program for future calibrations. If you had to align the machine to the laser beam, you could not easily reuse the same program, and you could not repeat the same measurement; repeating the same measurement provides a valuable comparison for assessing changes in machine performance.

The general procedure has these major steps:

1. **Installing the measurement optics on the machine.**
2. **Installing and initially aligning the laser head.**
3. **Aligning the beam to the XY plane diagonal (azimuth angle, α) of the measurement.**
4. **Aligning the beam to the elevation angle (β) of the measurement.**

Installing the measurement optics on the machine

This procedure is for a stacked-stage milling machine; that is, one whose table can move in X and Y. Adapt the procedure as necessary when you want to use some other setup.

This procedure assumes that you have performed the assembly procedures earlier in this guide.

This procedure has these major steps:

1. **Mounting the interferometer assembly on the machine table.**
2. **Installing the measurement retroreflector.**

Mounting the interferometer assembly on the machine table

To mount the interferometer assembly on the machine, follow these steps:

1. **Turn on the PC and start the HP 5529A software running.**
2. **On the Main Menu, select Other Meas.**

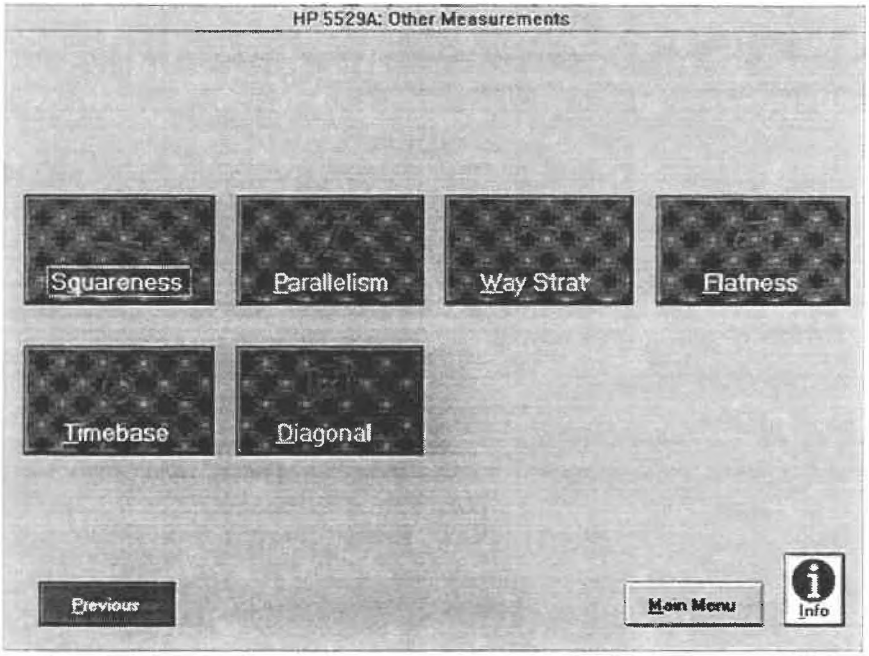
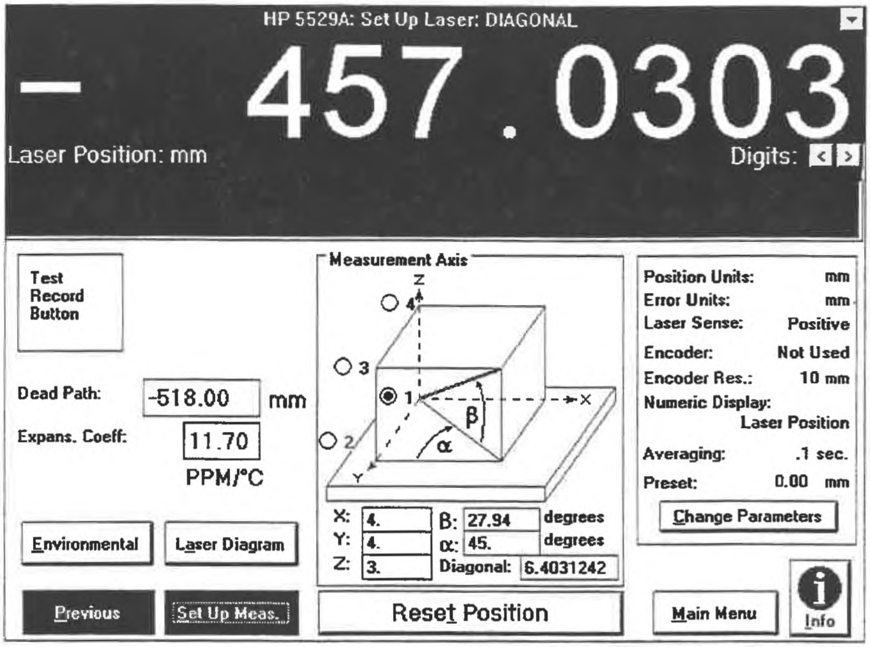

HP 5529A: Other Measurements
Squareness
Parallelism
Way Strat
Flatness
Timebase
Diagonal
Previous
Main Menu
Info

Figure 11–10. Other Measurements Window

3 **On the Other Measurements menus, select Diagonal.**


Test Record Button
Measurement Axis
Z
○ 4
○ 3
● 1
○ 2
X
Y
β
α
Environmental
Laser Diagram
Previous
Set Up Meas.
Reset Position
Change Parameters
Main Menu
Info

HP 5529A: Set Up Laser: DIAGONAL

– 457.0303

Laser Position: mm

Digits:

Dead Path: -518.00 mm

Expans. Coeff: 11.70 PPM/°C

X: 4.

Y: 4.

Z: 3.

β: 27.94 degrees

α: 45. degrees

Diagonal: 6.4031242

Position Units:	mm
Error Units:	mm
Laser Sense:	Positive
Encoder:	Not Used
Encoder Res.:	10 mm
Numeric Display:	Laser Position
Averaging:	.1 sec.
Preset:	0.00 mm

Figure 11–11. Diagonal Measurements—Set Up Laser Window

4 **Determine where on the machine you want to mount the interferometer-and-base assembly. The location depends on the machine, the type of measurement, and the space around the machine.**

5 **Set the adjustable triangle to the azimuth (α) angle the HP 5529A calibrator calculated for your measurement.**

6 **Establish a suitable reference surface on your machine's table (such as a "T" slot) and place the adjustable triangle against it (see Figure 11–26). When setting up the reference surface, be sure to allow for any offset between the edge of the interferometer assembly base and the actual location of the diagonal plane.**

7 **Place the interferometer assembly in position on the table, against the edge of the adjustable triangle. The interferometer's exit face should be pointing along the XY-plane diagonal of your measurement.**

8 **Carefully clamp the interferometer assembly base to the machine table.**

9 **Set the adjustable triangle to the elevation angle (β) the HP 5529A calibrator calculated for the body diagonal you are measuring.**

10 **Use the adjustable triangle to set the initial elevation angle of the interferometer assembly and beam steering arm (see Figure 11–27). For a coarser alignment, you can simply use the scale on the side of the beam steering arm assembly.**

11 **Set the adjustable triangle for 90 degrees.**

12 **Use the adjustable triangle against the table or the interferometer assembly base and the back of the beam steering mirror tray to set the beam steering mirror vertical.**

13 **Adjust the knob on the back of the beam steering mirror tray to set the mirror in its neutral position. The pointer on the knob should be in line with the mark on the tray.**

You will refine these initial adjustments in the procedures below.

Installing the measurement retroreflector

The measurement retroreflector is a cube corner having the property of redirecting an input beam back toward its source along a parallel line. Exact orientation of the retroreflector is not critical. This procedure assumes that you have already assembled the measurement retroreflector and ball-joint as described earlier.

1 **If necessary, remove any tool in the spindle.**

2 **Insert the free end of the ball-joint assembly into the spindle and tighten it in place.**

3 **Point the measurement retroreflector's face toward the interferometer's measurement face, align the retroreflector so these faces are parallel, then tighten the ball-joint screw to hold this alignment.**

Note You can slightly reduce the sensitivity of the measurement retroreflector to rotational motions of the spindle by placing the retroreflector's nodal point on the spindle's axis. In either retroreflector described here, the nodal point is about 12.6 mm (0.5 inch) behind the front surface of the glass. (See Figure 11–9.)

Installing and initially aligning the laser head

Use this procedure to install the laser head on the tripod and perform the initial alignment of the laser beam to the XY plane face diagonal of the measurement and parallel to the XY plane (table) of the machine. This alignment is important during measurement as the table carrying the interferometer moves.

1 **Place the tripod at the desired point for your measurement. The vertical centerline of the tripod should be in or near the vertical plane containing the body diagonal you will be measuring. For this autoreflection alignment procedure, the longer the distance from the laser head to the interferometer, the more accurate the alignment can be; the ideal distance is from 1 to 4 meters (3 to 12 feet).**

2 **Set the laser head on the tripod and secure it. Refer to the *HP 5529A Getting Started Guide* for details.**

3 **Connect the laser to its power source and turn it on.**

4 **Select the laser head's small output (upper) aperture, and the lower (return port) target, for alignment.**

5 **Adjust the laser head's and tripod's vertical and horizontal translation and pitch and yaw controls so the laser beam autoreflects from the beam steering mirror back to the laser head's output (upper) port.**

WARNING Never stare directly into the laser beam or any bright reflection of it. Failure to observe this warning may result in personal injury.

6 **Place the HP 10767-67001 alignment target (shown in Figure 11–2), with its hole up, over the front of the beam steering mirror. The front of the mirror tray has recesses that enable it to hold the target.**

7 **Adjust the tripod and laser head positioning controls so the beam autoreflects from the beam steering mirror back to the laser head's output (upper) port, through the hole in the target.**

8 **Remove the alignment target from the beam steering mirror.**

This completes the installation and initial alignment of the laser head.

Aligning the beam to the XY plane diagonal (azimuth angle, α) of the measurement

Use this procedure to improve laser beam alignment along the XY plane face diagonal.

In this procedure, you move a cube corner—in this case, the reference retroreflector attached to the interferometer—along the XY plane face diagonal and check for drifting of the return beam at the laser head.

To perform this procedure:

1 **Move the machine to place the interferometer assembly as close to the laser head as possible, without moving the laser head.**

Note Do not use the mirror tilt adjustment knob on the bottom of the mirror tray until instructed to do so.

2 **Rotate (pitch) the beam steering mirror so beam enters the interferometer perpendicular to its input face. The return beam from the reference retroreflector will produce a dot on the face of the laser head near the return (lower) port.**

Note An alternate procedure that may be easier here is to use a rubber band to hold a small gage block to the input face of the interferometer and use autoreflection back through the beam steering mirror to the laser head input port. Be sure to remove the gage block when done.

3 **Observe the return beam dot on the laser head's lower (return) port as you move the machine's table to increase the distance between interferometer and the laser head along the XY plane diagonal of the measurement. Continue moving the interferometer until you do not see the dot or until the end of travel is reached, whichever occurs first. If you lose sight of the dot before end of travel is reached, return the interferometer to the last position at which you saw the dot.**

If the dot drifts as the interferometer moves, the laser beam is not perfectly aligned to the travel path. The remainder of this procedure corrects that alignment.

4 **With the interferometer at its farthest travel point or at the last point at which a return dot was visible, yaw and pitch (turn and tilt) the laser head on the tripod as necessary to center the return beam on the lower port. You may speed your alignment procedure by doing some overcorrection, moving the dot to the other side of the lower port; experience will help you here.**

5 **Observe the return beam spot on the laser head's face as you use the machine to move the interferometer toward the laser head.**

6 **If the return beam spot moves, translate the laser head horizontally and vertically, without turning it, so most or all of the return beam from the interferometer will enter the lower port. Do not overcorrect on your translation adjustments.**

7 **Repeat steps 3 through 7 until the return beam from the interferometer can enter the laser head's lower port at all interferometer positions along the XY plane diagonal.**

Now your setup is ready for aligning to the actual measurement (body) diagonal. **Do not make any more changes to the laser head or tripod position controls until instructed to do so.**

Aligning the beam to the elevation angle (β) of the measurement

This procedure assumes that you have performed the assembly, installation, and alignment procedures above. This means that the laser head has already been aligned to the XY diagonal (azimuth) path of your measurement, and you should only need to adjust the beam steering mirror to direct the beam toward the measurement retroreflector moving along the measurement diagonal.

It is likely that, no matter how precise you have tried to be in your setup, you will have to make some alignment adjustments. Here, previous experience performing distance (linear) alignments can be a help as you align the optics.

1 **Move the machine spindle and table to place the measurement retroreflector close to the output face of the interferometer.**

2 **Adjust the measurement retroreflector so its face is parallel to and centered on the interferometer's measurement face (the one facing along the measurement path).**

3 **At this time, the measurement retroreflector should be providing a return beam to the front of the laser head. If the return beams from the two retroreflectors overlap, you will see only one dot.**

Note You may have to reposition the measurement retroreflector slightly in order to overlap the measurement beam dot and reference beam dot on the laser head's input port.

Note If you want to see only the dot from the measurement path return beam, remove the reference retroreflector from the interferometer, being careful not to disturb the interferometer alignment. Be sure to replace this retroreflector before you try to make a measurement.

Another way to identify the measurement beam dot during alignment is to use your hand to momentarily interrupt the measurement path beam.

4 **Observe the measurement beam dot as you move the machine to increase the distance between the interferometer and the measurement retroreflector along the body diagonal.**

Continue moving the interferometer and measurement retroreflector until the moving dot disappears or until the end of travel is reached, whichever occurs first. If the dot disappears before end of travel is reached, return the interferometer to the last position at which you saw the dot.

Movement of the measurement beam dot indicates that the measurement beam was not perfectly aligned to the work zone body diagonal. If the dot moves, perform steps 5 through 9 below.

5 **Slightly rotate the beam steering mirror to move the measurement return dot back to the laser head's return port. You may also have to make a slight adjustment of the knob on the bottom of the mirror tray to do this.**

6 **Move the machine to return the measurement retroreflector and the interferometer to their close-together position.**

7 **If necessary, reposition the measurement retroreflector so its return dot overlaps the dot from the reference retroreflector attached to the interferometer. (If you removed the reference retroreflector earlier, you should re-attach it now.)**

8 **If necessary, slightly translate the laser head, without turning it, so the overlapping dots are over its lower (return) port.**

9 **Repeat steps 3 through 9 to verify satisfactory alignment, indicated by both dots remaining stationary on the laser head's return port as the measurement optics are moved through the entire measurement travel range.**

10 **When the alignment is satisfactory,**

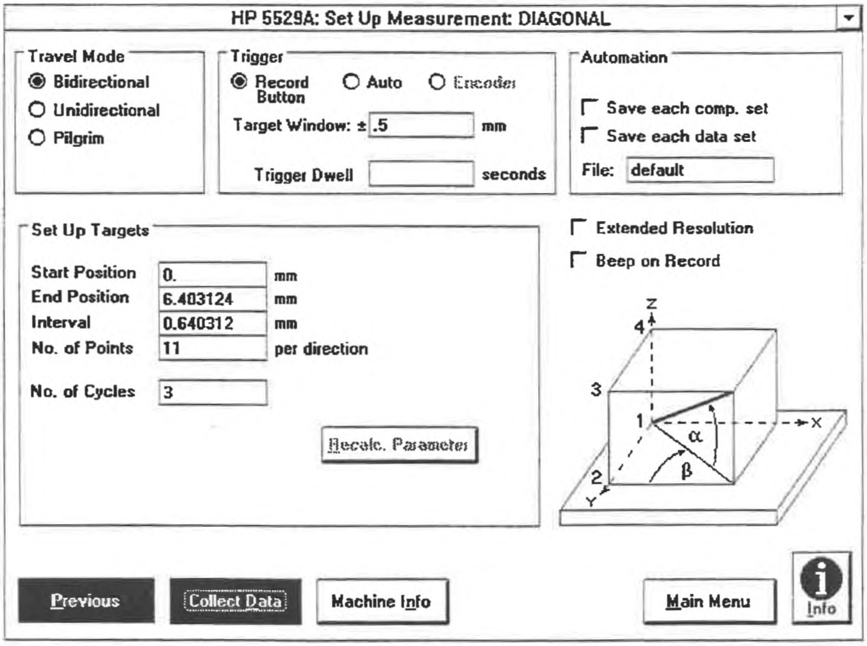
   a. Tighten all adjustment locks to keep settings from changing.

   b. Repeat steps 3 through 8, to be sure nothing has changed.

Making your measurement

Guide: This information relates to flowchart items **7** through **10**.

1 **After you have finished aligning the measurement optics to the diagonal path to be measured, select Set Up Meas on the HP 5529A's Set Up Laser window.**



HP 5529A: Set Up Measurement: DIAGONAL

Travel Mode
● Bidirectional
○ Unidirectional
○ Pilgrim

Trigger
● Record Button ○ Auto ○ Encoder
Target Window: ± .5 mm
Trigger Dwell seconds

Automation
☐ Save each comp. set
☐ Save each data set
File: default

☐ Extended Resolution
☐ Beep on Record

Set Up Targets

Start Position	0.	mm
End Position	6.403124	mm
Interval	0.640312	mm
No. of Points	11	per direction
No. of Cycles	3	

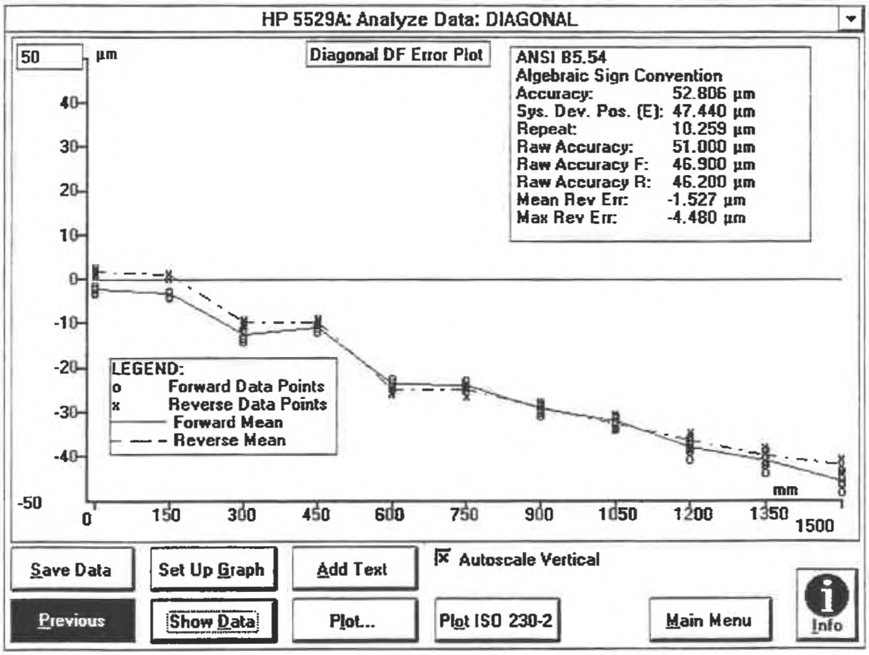
Figure 11–12. Diagonal Measurements—Set Up Laser Window

2 **Make any changes to the setup required for your situation, then press Collect Data.**

At its simplest, a diagonal measurement is a linear distance measurement along a line that is not necessarily parallel to nor perpendicular to one or more of the machine's major axes (X, Y, or Z). As such, a diagonal measurement is subject to the same accuracy problems as any other laser linear distance measurement. For more information about this, read the appropriate information in your measurement system documentation. In particular, see the discussion of cosine error.

3 **In the absence of any special instructions, record and save your diagonal measurement data in the same way you take your linear distance measurement data.**

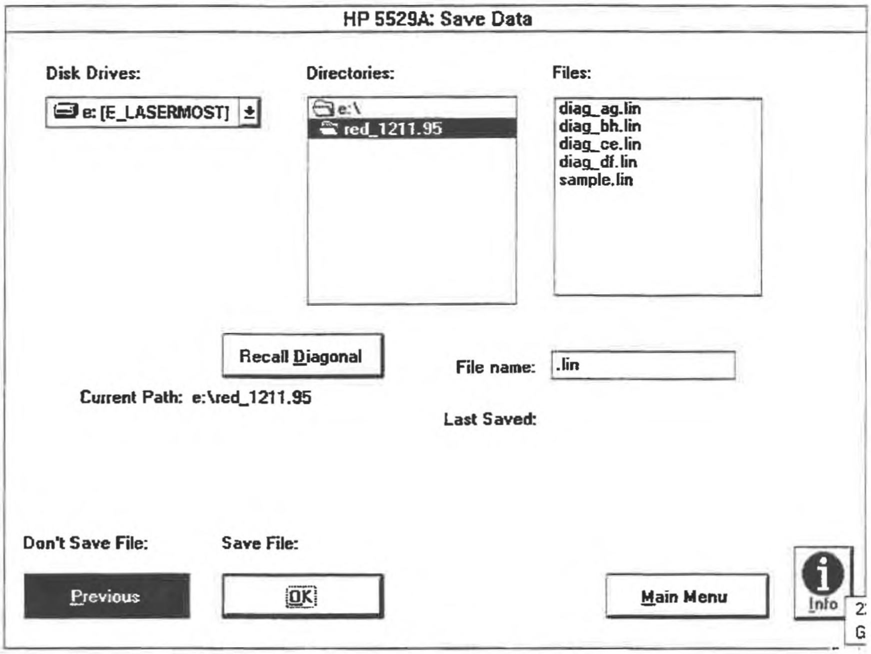
After the HP 5529A calibrator has finished collecting the required data, it will automatically switch to the Analyze Data window.


HP 5529A: Analyze Data: DIAGONAL
Diagonal DF Error Plot
50
µm
40
30
20
10
0
-10
-20
-30
-40
-50
0
150
300
450
600
750
900
1050
1200
1350
1500
mm
LEGEND:
o Forward Data Points
x Reverse Data Points
Forward Mean
Reverse Mean
Save Data
Set Up Graph
Add Text
☒ Autoscale Vertical
Previous
Show Data
Plot...
Plot ISO 230-2
Main Menu
Info

ANSI B5.54
Algebraic Sign Convention
Accuracy: 52.806 µm
Sys. Dev. Pos. (E): 47.440 µm
Repeat: 10.259 µm
Raw Accuracy: 51.000 µm
Raw Accuracy F: 46.900 µm
Raw Accuracy R: 46.200 µm
Mean Rev Err: -1.527 µm
Max Rev Err: -4.480 µm

Figure 11–13. Analyze Data: DIAGONAL window (following Collect Data Window)

4 **Select Save Data to save your data for this diagonal.**



HP 5529A: Save Data

Disk Drives: e: [E_LASERMOST]

Directories:
e:\
red_1211.95

Files:
diag_ag.lin
diag_bh.lin
diag_ce.lin
diag_df.lin
sample.lin

File name: .lin

Current Path: e:\red_1211.95

Last Saved:

Figure 11–14. Save Data window

5 **Specify the file name you want to use. In order to be usable in the Diagonal Measurement analysis, it must end in ".lin".**

Note Do not select Recall Diagonal during this part of the procedure.

6 **Select Main Menu.**

If the your data was for the first diagonal in the plane you are measuring, continue with "Aligning for the second diagonal in the same plane", below.

If your data was for the second diagonal in the first plane, you will have to move the laser head and begin the alignment procedure for the second plane. Go back to "Installing the measurement optics on the machine" text. Note that you must not change the measurement setup values from those of the previous measurements you have made for this diagonal analysis.

If your data was for the fourth diagonal to be used in your analysis, go to "Analyzing your data", below

Aligning for the second diagonal in the same plane

Alignment to the “far low to near high” diagonal in this plane is similar to the procedure above for the first diagonal (“near low to far high”). However,

Note Do not move the laser head. The beam is already aligned for the second diagonal.

- The interferometer assembly is moved to the position on the table where it intersects the second diagonal; that is, the opposite end of the diagonal plane of the work zone being calibrated.
- The interferometer and beam steering mirror angles must be reset as required for the new measurement. Again, you can use the adjustable triangle to provide a more accurate initial setup. Refer to Figures 11–5 through 11–7 to determine what might be the best setup for your second-diagonal measurement.
- The measurement retroreflector must be reoriented, to return the measurement beam to the interferometer in its new location.

Analyzing your data

Guide: This information relates to flowchart items **12** through **14**.

1 **If you are not already at the HP 5529A calibrator's Main Menu, go there.**

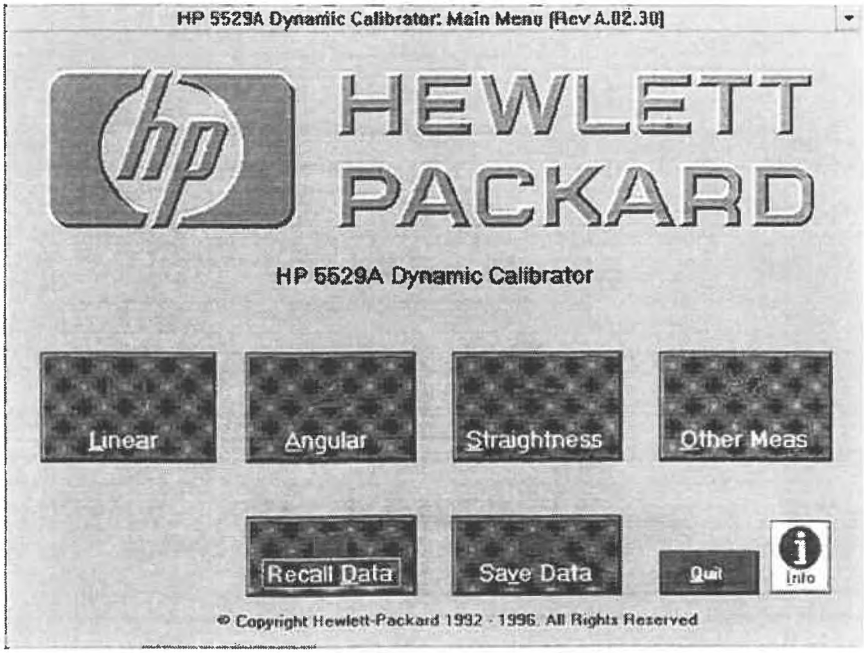
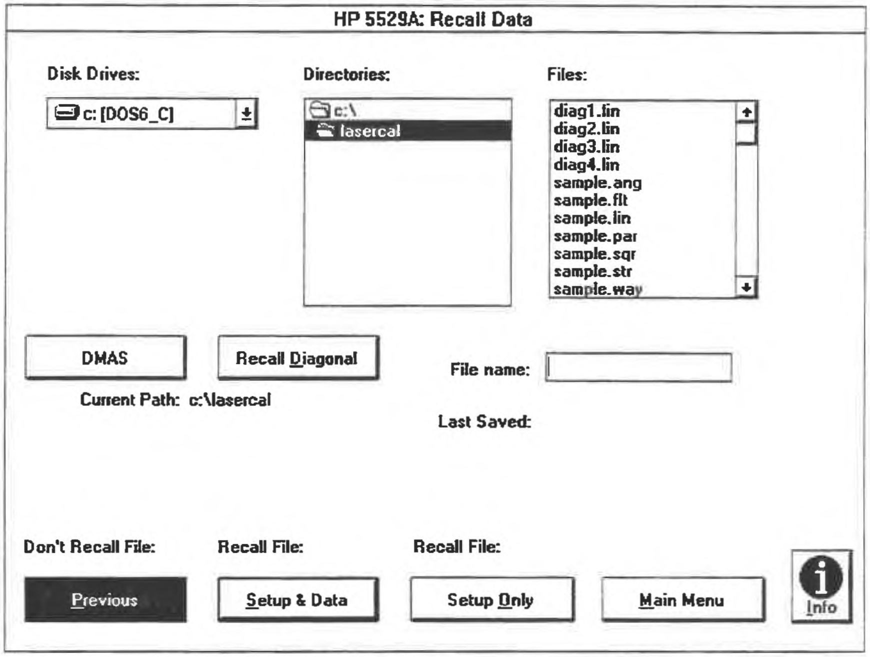

HP 5529A Dynamic Calibrator: Main Menu (Rev A.02.30)
HEWLETT PACKARD
HP 5529A Dynamic Calibrator
Linear
Angular
Straightness
Other Meas
Recall Data
Save Data
Quit
Info
© Copyright Hewlett-Packard 1992 - 1996. All Rights Reserved

Figure 11–15. HP 5529A Calibrator—Main Menu

2 **Select Recall Data.**



HP 5529A: Recall Data

Disk Drives: c: [DOS6_C]

Directories: c:\ lasercal

Files:
diag1.lin
diag2.lin
diag3.lin
diag4.lin
sample.ang
sample.flt
sample.lin
sample.par
sample.sqr
sample.str
sample.way

Current Path: c:\lasercal

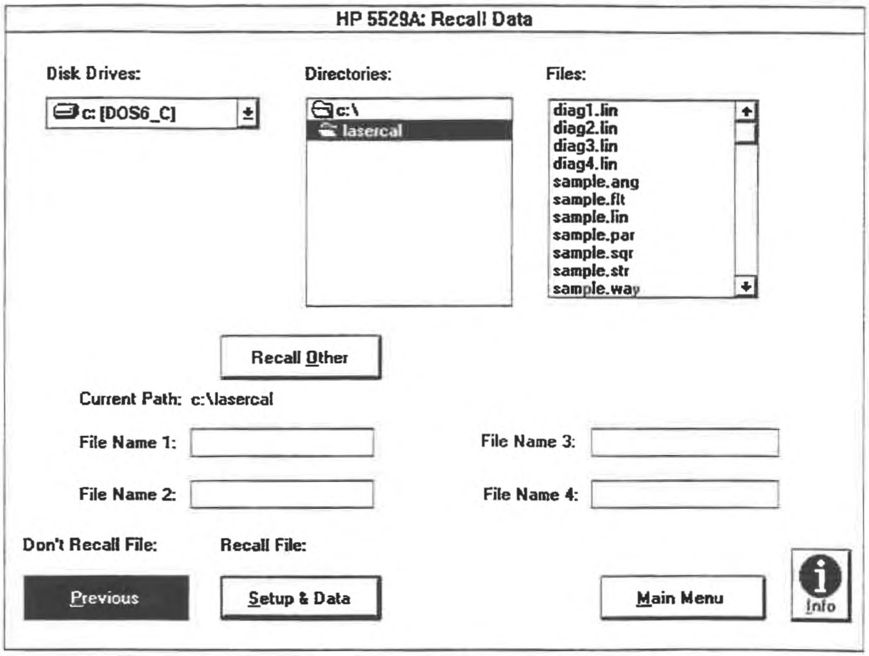
File name:

Last Saved:

DMAS
Recall Diagonal
Don't Recall File:
Previous
Recall File:
Setup & Data
Recall File:
Setup Only
Main Menu
Info

Figure 11–16. HP 5529A Calibrator—Recall Data window

3 Select Recall Diagonal.


HP 5529A: Recall Data
Disk Drives:
c: [DOS6_C]
Directories:
c:\
lasercal
Files:
diag1.lin
diag2.lin
diag3.lin
diag4.lin
sample.ang
sample.flt
sample.lin
sample.par
sample.sqr
sample.str
sample.way
Recall Other
File Name 1:
File Name 2:
File Name 3:
File Name 4:
Don't Recall File:
Recall File:
Previous
Setup & Data
Main Menu
Info

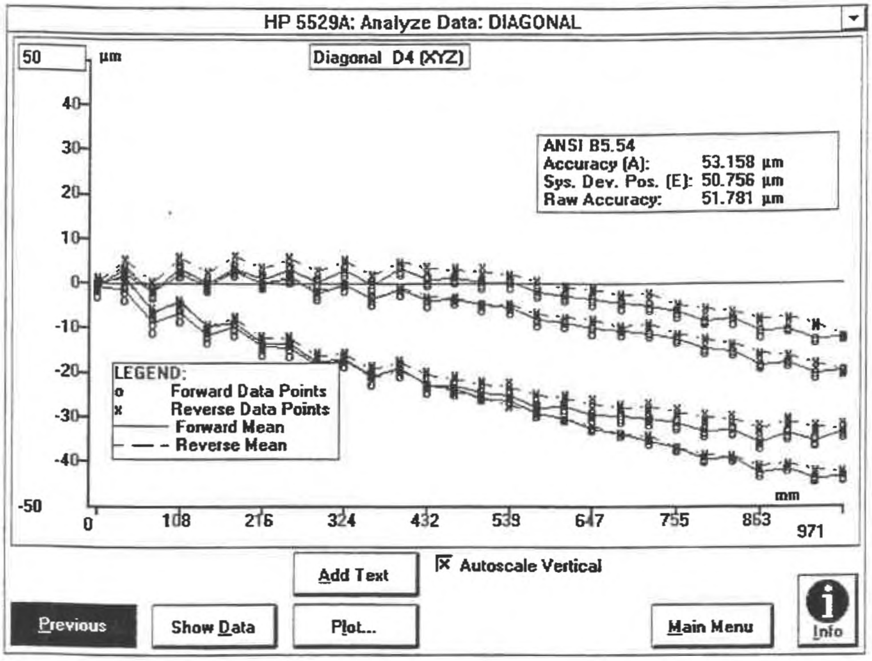
Current Path: c:\lasercal

Figure 11–17. HP 5529A Calibrator—Recall Data window (following Recall Diagonal)

4 **Specify the four ".lin" files you want to use in your analysis.**

5 **Select Setup & Data.**

The Analyze Data window, showing the data from the four files you have selected.


HP 5529A: Analyze Data: DIAGONAL
50
µm
Diagonal D4 (XYZ)
40
30
20
10
0
-10
-20
-30
-40
-50
LEGEND:
o Forward Data Points
x Reverse Data Points
Forward Mean
- — - Reverse Mean
mm
0
108
216
324
432
539
647
755
863
971
Add Text
Previous
Show Data
Plot...
Main Menu
Info

ANSI B5.54
Accuracy (A): 53.158 µm
Sys. Dev. Pos. (E): 50.756 µm
Raw Accuracy: 51.781 µm

☒ Autoscale Vertical

Figure 11–18. HP 5529A Calibrator—Analyze Data: DIAGONAL window (following Recall Data)

Slant-bed lathe

Guide: This information relates to flowchart item **15**.

The HP 10768A kit optics can also be used to calibrate a slant-bed lathe, without tilting the laser head.

The HP 10768-60201 Beam Steering mirror assembly that was developed for the Diagonal Measurement application is used to simplify the setup for measurements on a slant-bed lathe. (Slant-bed lathes can also be measured with the HP 10769A Beam Steering Mirror, which provides the beam steering assembly and some additional mounting hardware.)

1 Laser head on tripod
2 Spindle
3 Interferometer and Beam steering assembly
4 Retroreflector
5 Tool Turret
6 Bed

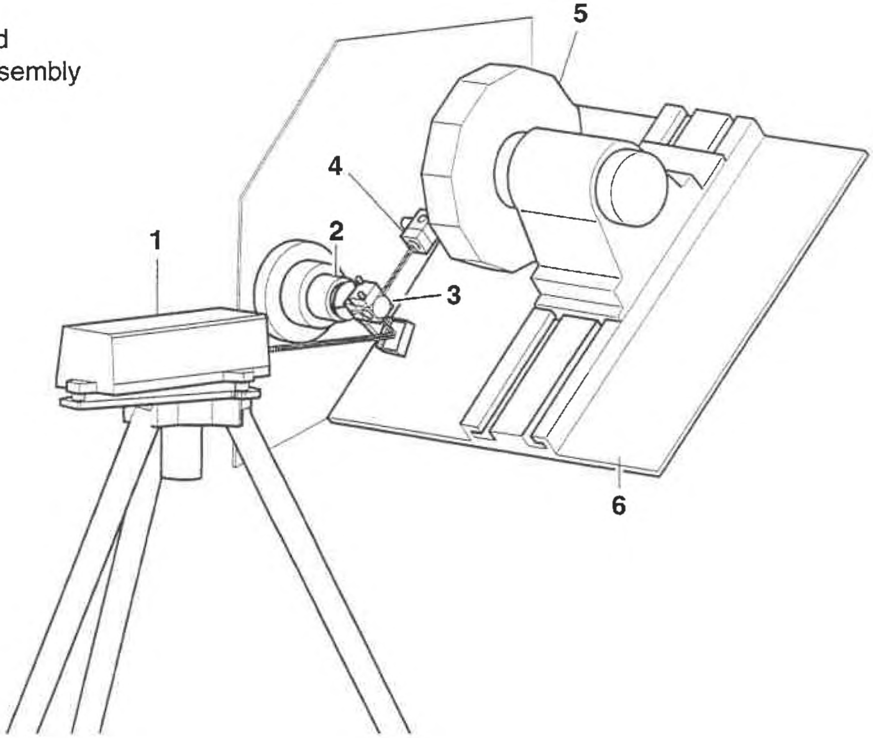


Figure 11–19. Setup for Slant-bed Lathe

1	Laser head on tripod
2	Spindle
3	Interferometer and Beam steering assembly
4	Retroreflector
5	Tool Turret
6	Bed

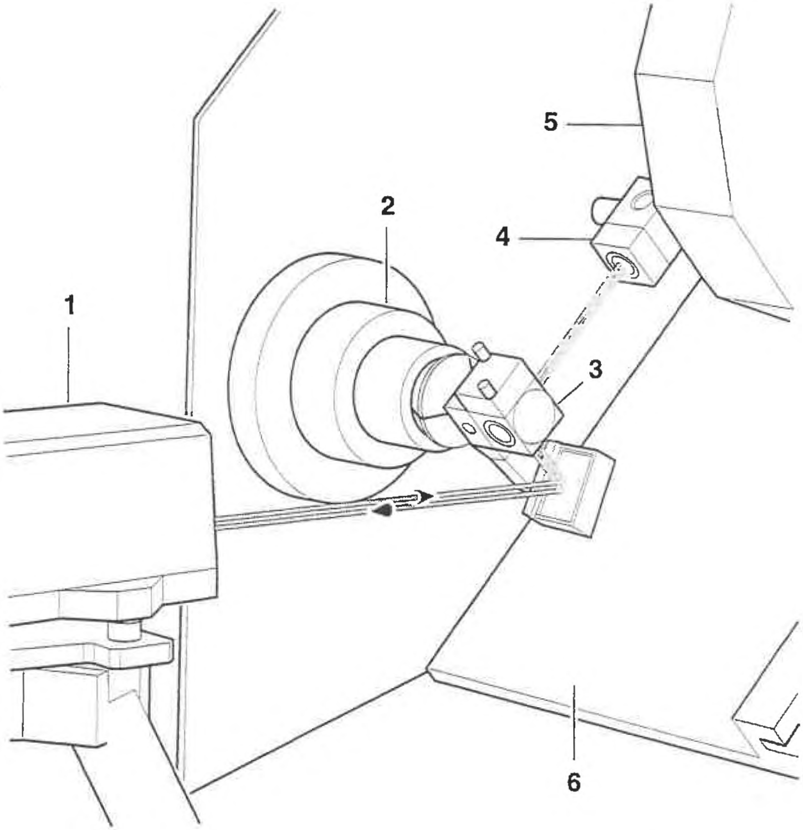


Figure 11–20. Setup for Slant-bed Lathe—Detail

Basics

- The interferometer has three configurations (see Figure 11–10). Configurations are named for the direction in which the beam from the laser head is bent, when viewed as shown.
- Laser beams enter and leave the interferometer perpendicular to its faces.
- The beam steering assembly allows a range of (elevation) angles between the laser head and the interferometer (see Figure 11–9). The minimum angle is just before the corner of the interferometer clips the beam between the laser head and the steering mirror. The maximum angle is just before the mirror no longer reflects enough of the beam to enable a measurement. Note that the angles shown in Figures 11–22 through 11–24 are only those between the interferometer and the incoming laser beam; the allowable measurement elevation angle can be anywhere from 0 to 180 degrees with respect to a horizontal plane, however no single interferometer configuration allows the beam to be used throughout this range (see Figures 11–5 through 11–7, and Table 11–1).
- Two beam paths are involved in the interferometer's measurement arm—the beam from the laser head and the beam returned to the receiver in the laser head.

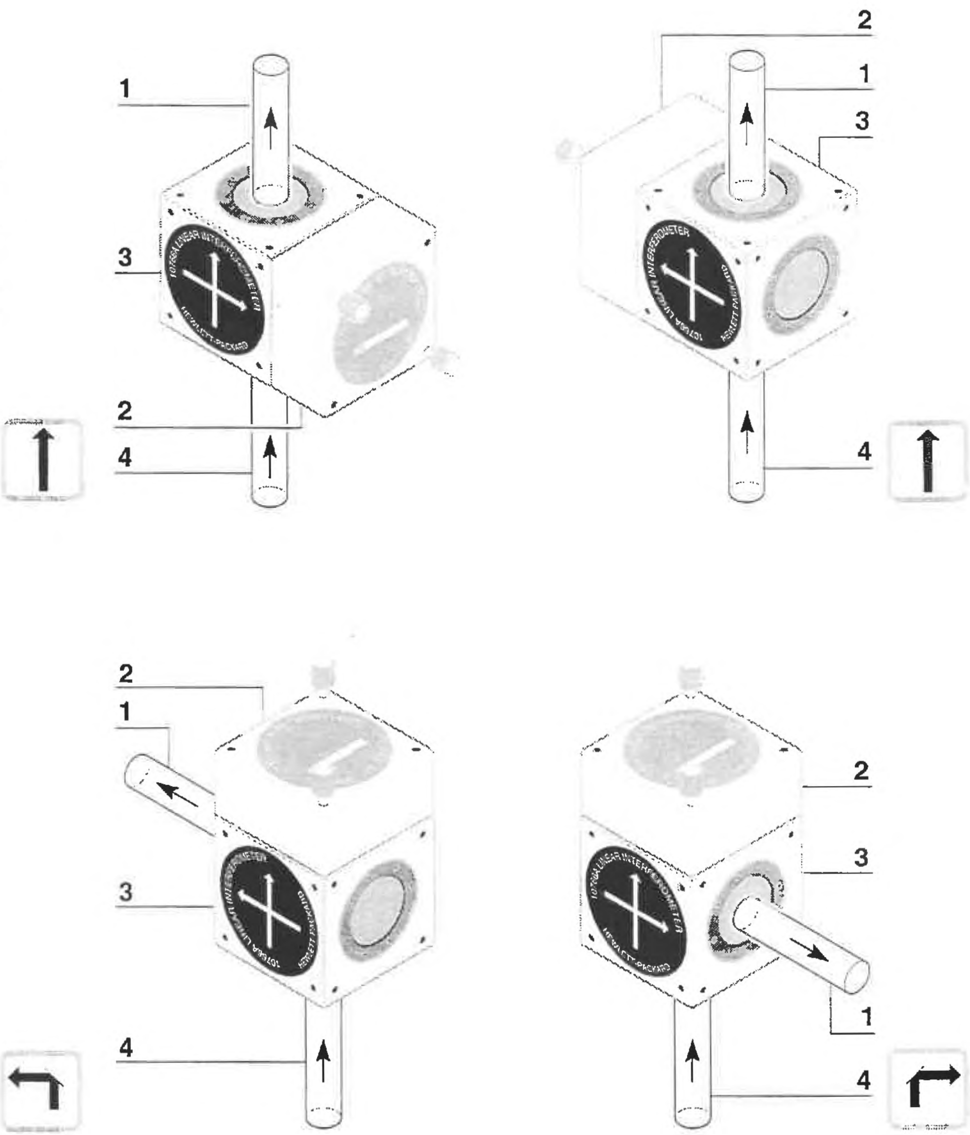
  Whenever a measurement configuration (typically a "far low to near high" general configuration) directs the measurement path back toward the laser head, the relationship of the two beams is inverted from that normally occurring at the interferometer (see Figure 11–25). Keeping this in mind can help you understand and use alignment procedures.
- For procedures in this chapter, azimuth angles (angles on the XY (horizontal) plane) are measured with respect to the X-axis or a line parallel to it (see Figure 11–4 or 11–26).
- Elevation angles (measured in the vertical plane containing the diagonals) are measured with respect to the XY plane or a plane parallel to it. (See Figure 11–4 or 11–27.) The

maximum elevation angle for any measurement type is 90 degrees. The minimum elevation angle is 0 degrees. When the elevation angle has crossed through either 90 or 0 degrees, the measurement configuration has changed; see Figure 11–5 through 11–7.

- When using the adjustable triangle for alignment, you can use secondary references as required. For example if the azimuth angle is less than 45 degrees, you can use the Y-axis as the reference. (See Figure 11–26.)
- In general, aligning the laser beam for a body diagonal measurement is the same as aligning the beam for any other linear (distance) measurement, except—you have one more optical element, and the diagonal path doesn't provide a reference surface that allows you to use true square for initial autoreflection alignment before placing the measurement optics. Thus, you must move the optics on the machine along the diagonal path to achieve final alignment.
- A pair of body diagonals is contained in a single vertical plane. The four body diagonals are contained in a pair of intersecting vertical planes.
- The laser beam must be aligned in the vertical plane containing the body diagonal(s) you are measuring (or in a plan parallel to it).
- The interferometer and beam steering assembly may be at either end of a diagonal path.
- The laser head may be to the left or right of the interferometer, when viewed from the side.
- Measurements and measurement setups in this chapter are identified in terms of the end points of the diagonal involved. The first term identifies the interferometer's position, the second term identifies the measurement retroreflector's position at the opposite end of the diagonal. "Near" and "far," refer to end points of the body diagonals in relation to the laser head's physical position. "Low" and "high" refer to the end points of a body diagonal in relation to each other.

1 Laser beam to measurement retroreflector
2 HP 10767A linear retroreflector
3 HP 10766A linear interferometer
4 Laser beam from laser head

See Table 11-1 for explanation of symbols.


1
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2
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2
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1
4
10766A LINEAR INTERFEROMETER
HEWLETT-PACKARD

Figure 11–21. Interferometer Configurations

1 HP 10766A linear interferometer
2 Beam-steering arm
3 Beam steering mirror
4 Beam from laser head
5 Beam to interferometer
6 Angle between beams:
30 ° minimum,
120 ° maximum

See Table 11–1 for explanation of symbols.

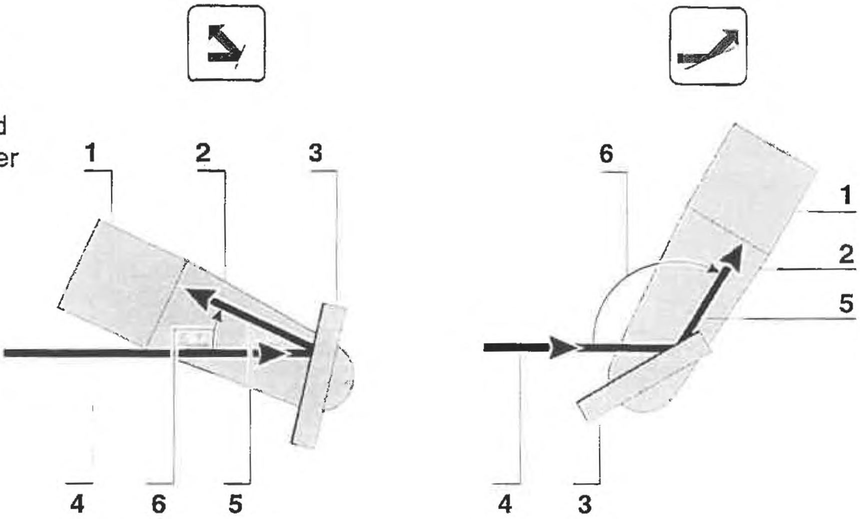


Figure 11–22. Beam Steering Angle Ranges

1	Measurement retroreflector
2	Measurement retroreflector (alternate position)
3	Elevation angle range: 30 to 90 degrees
4	Elevation angle range: 0 to 60 degrees
5	Linear interferometer
6	Beam-steering arm with interferometer
7	Laser head on tripod
8	Machine table

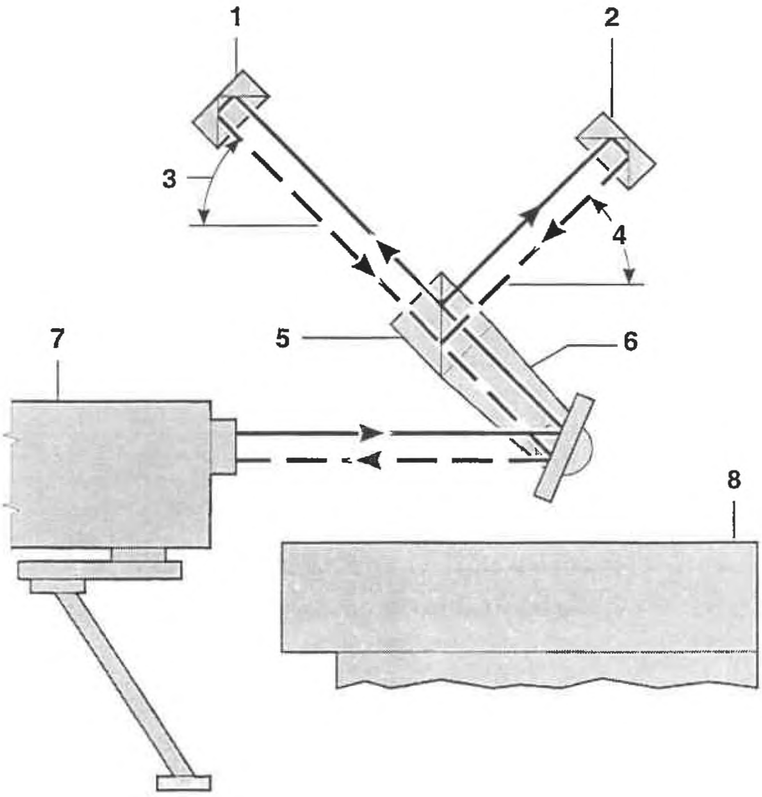


Figure 11–23. Diagonal Measurement Optics—Configuration 1

1	Measurement retroreflector
2	Measurement retroreflector (alternate position)
3	Elevation angle range: 30 to 90 degrees
4	Elevation angle range: 0 to 60 degrees
5	Linear interferometer
6	Beam-steering arm with interferometer
7	Laser head on tripod
8	Machine table

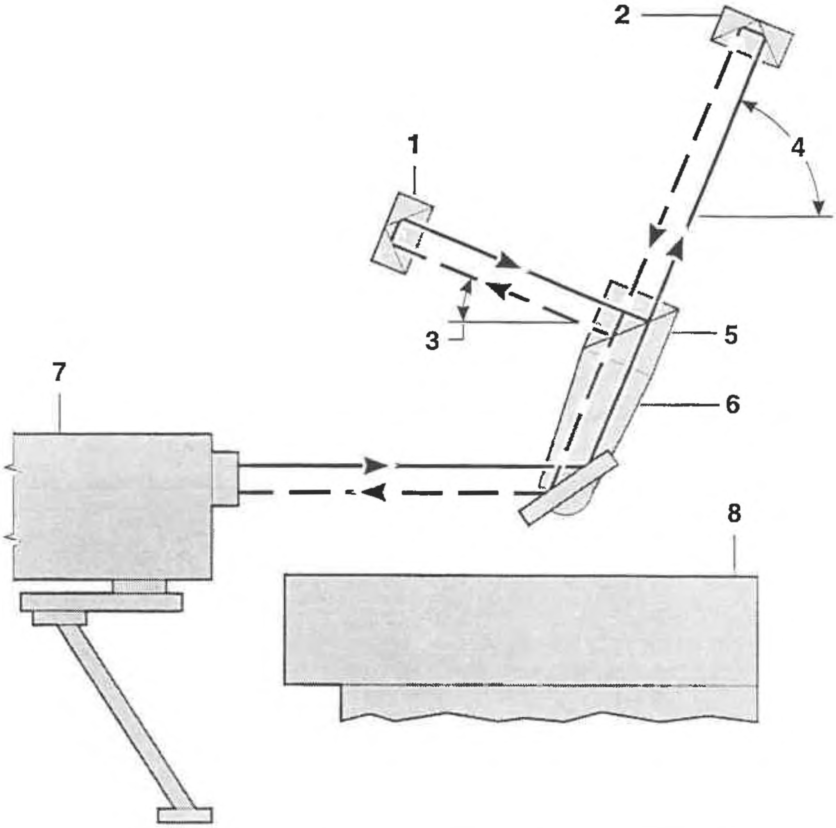
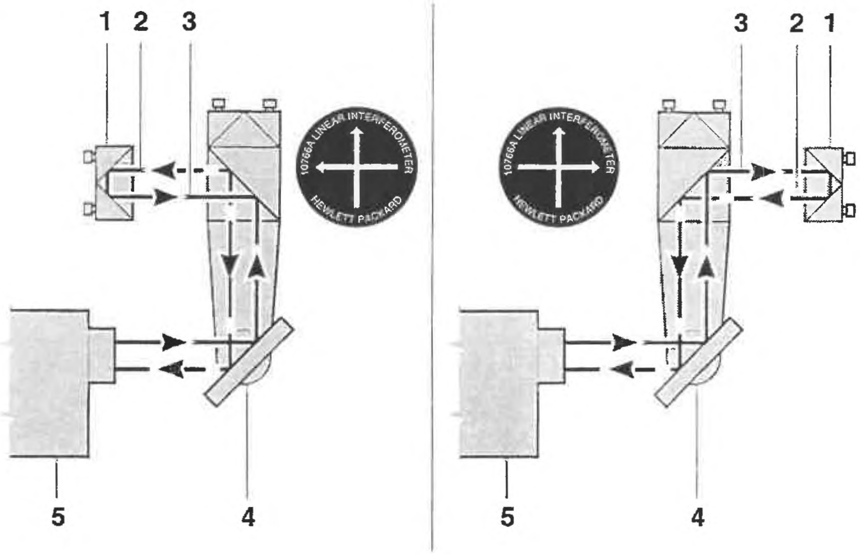


Figure 11–24. Diagonal Measurement Optics—Configuration 2

1 Measurement retroreflector
2 Return beam to laser head
3 Outgoing beam from laser head
4 Beam-steering arm assembly with interferometer
5 Laser head

See Table 11–1 for explanation of symbols.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3
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HEWLETT PACKARD
5
4
3
2
1
10766A LINEAR INTERFEROMETER
HEWLETT PACKARD
5
4

Figure 11–25. Two Beams

1	Laser beam along diagonal plane
2	Machine table top
3	Base
4	Y-axis or parallel line on machine table top
5	Laser Head
6	Adjustable triangle
7	X-axis or parallel line on machine table top

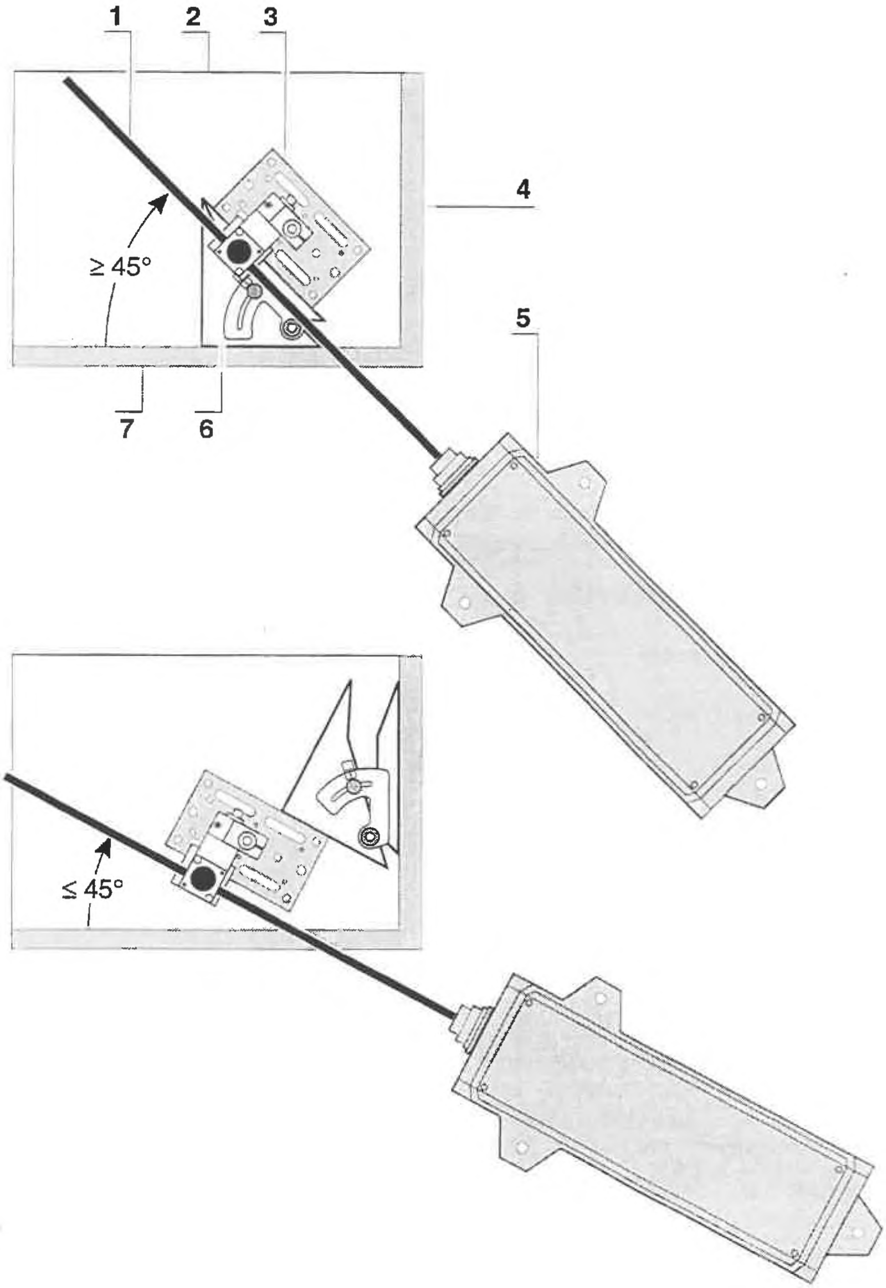

Figure 11–26. Setting the XY Plane Diagonal Angle Using the Adjustable Triangle

1 Adjustable triangle
2 Beam steering assembly with interferometer and reference retroreflector
3 Beam to measurement retroreflector
4 Elevation angle between horizontal plane and beam
5 Horizontal reference plane
6 Beam from laser head

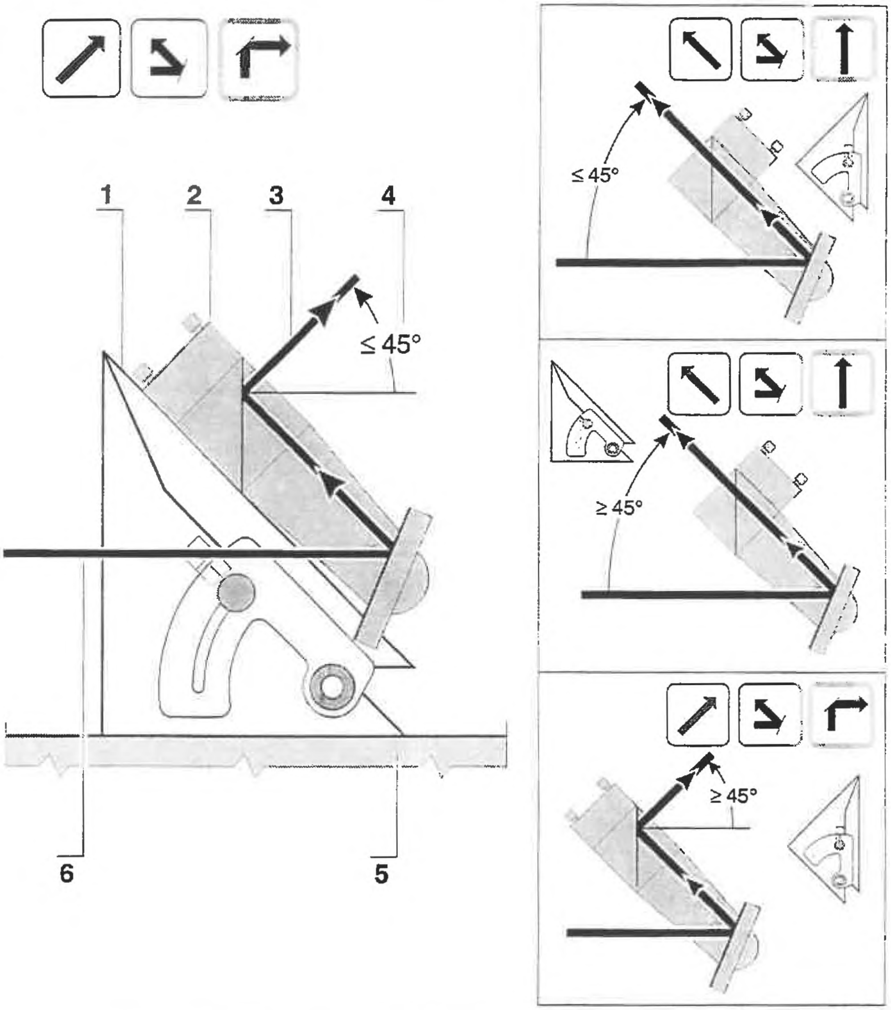

Figure 11–27. Setting the Elevation Angle Using the Adjustable Triangle

Characteristics

HP 10768A Diagonal Measurement Kit and HP 10769A Beam-steering Mirror

Weight:	10768-60201	Beam steering assembly: 354 g (12.5 oz)
	10768-20207	Right angle clamp: 68 g (2.4 oz)
	10768-60203	Ball-joint assembly: 123 g (4.3 oz)
	10768-20215	Adapter plate: 36 g (1.3 oz)
	10785-20005	Post–long: 228 g (8.0 oz)
	10776-20008	Post–medium: 111 g (3.9 oz)
	10768-20213	Post–stub: 42 g (1.5 oz)
	10767-67001	Alignment Target: 11 g (0.39 oz)
	10768-20214	Base–large: 832 g (29.3 oz)
	HP 10767B	Lightweight retroreflector: 34.7 g (1.2 oz)
	10767-20203	Clamp Nut (used with HP 10767B retroreflector): 4.6 g (0.16 oz)

Mirror: Coating: Hard dielectric
Clear aperture: central oval 25 mm × 45 mm (1.0 × 1.8 in)
Flatness: 1/10 wavelength at 633 nm
Reflectance: ≥ 90% over incidence range of 0 ° to 60 ° at 633 nm (both s and p polarizations)

Adjustable Ball-joint threads: M10×1.5, M8×1.25

Modes of use:

1. Linear interferometer attached to Beam-steering arm assembly for diagonal measurements.
2. Linear interferometer mounted remotely from Beam-steering arm assembly for diagonal measurements.
3. Linear interferometer attached to Beam-steering arm for slant-bed lathe calibration.
4. Beam-steering arm alone as Beam-steering mirror.

A. Operating specifications

A. Operating specifications

A

Operating Specifications

Operating specifications

This appendix lists the operating specifications for the HP 5529A dynamic calibrator.

Table A-1. General specifications

Characteristic	**Specification**
Axis velocity 5519A 5519B[1]	 700 mm (27.6 in) per second 1000 mm (39.4 in) per second
Power requirements — electronics	2.6 A at 5 Vdc; 15 mA at 12 Vdc from the PC
10886A	5V 1 Amp (Typical with all sensors)
10887P	5 V 1.8 Amp +12V 40 MA -12V 20 MA
Data rate	greater than or equal to 1 KHz standard; greater than or equal to 100 Hz with extended resolution
A quad B differential input threshold	±0.5 V minimum; ±7.0 V maximum
A quad B differential input impedance	100 Ohms or high-impedance
A quad B input rate	7.5 MHz maximum

[1] The higher axis velocity is available with the HP 5519B and HP 10887 Axis boards with serial prefixes above 3546A.

Table A–2. Laser specifications

Characteristic	**Specification**
Type	helium-neon with automatically tuned Zeeman-split two-frequency output
Warm-up time	less than 10 minutes (typically 4 minutes)
Operating temperature	0 ° to 40 °C (32 ° to 104 °F)[1]
Power requirements—laser head	100 to 120 Vac, 48 to 66 Hz and 400 Hz; 220 to 240 Vac, 48 to 66 Hz; 50 W during warm-up, 33 W after warm-up
Vacuum wavelength	632.991354 nm
Wavelength accuracy	±0.1 ppm
Short-term (1 hour) wavelength stability	±0.002 ppm typical
Long-term (lifetime) wavelength stability	±0.02 ppm typical
Maximum output power	1 mW
Beam diameter	6 mm (0.24 in)
Beam centerline spacing	11.0 mm (0.43 in) input to output aperture
Safety classification	Class II laser product conforming to U.S. National Center for Devices and Radiological Health Regulations 21 CFR 1040.10 and 1040.11

[1] Optics temperature must be stabilized to ±2 °C (3.6 °F) to achieve accuracy specifications.

Table A–3. Environmental compensation specifications

Characteristic	Specification
Maximum compensation update rate	0.5 Hz[1]
Wavelength of light (WOL) compensation[2]	Automatic calculation or Manual entry. Automatic calculation requires HP 10751C,D Air Sensor. Air pressure, temperature, relative humidity, and computed WOL provided on the display. Manual entry is via keyboard. Range: 0.1000000 to 1.0000000 ppm.
Air temperature operating range	0 ° to 40 °C (32 ° to 104 °F)
Absolute pressure	517.2 to 775.7 mm Hg (20.4 to 30.5 in) (10–15 psia)
HP 10751C,D air sensor heat dissipation	2 W typical
HP 10751C,D air sensor time constants	7 minutes typical for air temperature; less than 1 second typical for absolute pressure

Table A-3. Environmental compensation specifications (continued)

Material Temperature Compensation	Automatic calculation or Manual entry. Automatic calculation requires 1 to 3 HP 10757D,E,F Material Temperature Sensors. Output of each connected sensor, and average of all, is provided on the display. Manual entry is via keyboard.
Material temperature sensors operating range[3]	0° to 50° C (32° to 122° F)
HP 10757D,E,F material temperature sensor time constant	40 seconds typical; 30 seconds typical with oil between mounting surface and sensor[4]
HP 10757D,E,F material temperature sensor maximum error[5]	±0.35° C (0.63° F) when calibrated alone; ±0.1° C (0.18° F) when calibrated with the HP 10886A PC compensation board
Material Expansion Coefficient:	Range: -100.0 to +100.0 ppm per °C or °F, manually entered.

[1] Combined wavelength of light (WOL) and material temperature compensation.

[2] WOL compensation is based on the HP 10751C,D air sensor.

[3] Material temperature compensation is based on the HP 10757D,E,F material temperature sensors.

[4] A drop of oil between the mounting surface and the sensor improves heat conductivity.

[5] Based on a 12-month calibration cycle and taking into account the effects of sensor aging over 12 months.

Table A-4 Linear and Diagonal measurement specifications

Characteristic	**Specification**
Linear optics resolution (HP 10766A)	10 nm (0.4 µin) standard; 1 nm (0.04 µin) extended
Plane mirror optics resolution[1] (HP 10706A,B[2] or HP 10705A-C03[3])	5 nm (0.2 µin) standard; 0.5 nm (0.02 µin) extended
High resolution plane mirror optics resolution[4] (HP 10716A)[2]	2.5 nm (0.1 µin) standard; 0.25 nm (0.01 µin) extended
Measurement range	40 m (130 ft) standard; 80 m (260 ft) optional
Measurement Accuracy	Temperature: 20° ± 0.5° C Using HP 10751C,D Air Sensor: ±1.5 ppm In Vacuum[5]: ±0.1 ±0.02 ppm
	Temperature: 15–25° C Using HP 10751C,D Air Sensor: ±1.7 ppm In Vacuum[5]: ±0.1 ±0.02 ppm
	Temperature: 0–40° C Using HP 10751C,D Air Sensor: ±3.0 ppm In Vacuum[5]: ±0.1 ±0.02 ppm

[1] For plane mirror optics: the maximum axis velocity is ±350 mm per second (±14 inches per second) using the HP 5519A laser head, or ±500 mm per second (±19 inches per second) using the HP 5519B.

[2] Requires the HP 10724A Plane Mirror Reflector. Since alignment of these optics is much more sensitive than for linear optics, linear optics are recommended for general use.

[3] Requires the HP 10704A retroreflector attached to the HP 10705A-C03. Also requires a measurement retroreflector: either a second HP 10704A or an HP 10767A

[4] For high resolution plane mirror optics, the maximum axis velocity is ±175 mm per second (±7 inches per second).

[5] Vacuum accuracy is ±0.02 ppm if the laser head is calibrated to MIL-STD 45662..

Note Velocity measurements use the linear optics. See Table A–4 for linear specifications.

Table A–5. Velocity measurement specifications

Characteristic	Specification
Measurement accuracy	0.02 percent of displayed value
Measurement resolution	0.01 mm (0.004 in) per second

Table A–6. Angular measurement specifications

Characteristic	Specification
Angular optics resolution	0.05 arcsec standard; 0.005 arcsec extended
Measurement accuracy	±0.2 percent of displayed value; ±0.05 arcsec per meter of travel by the moving optic. The optics can be Mil Std calibrated for higher accuracy.
Measurement range	±10 degrees rotated about the base of the optic; ±20 degrees rotated about the center of the optic
Maximum distance between the laser head and reflector	less than or equal to 15 m (50 ft)

Table A–7. Straightness measurement specifications

Characteristic	**Specification**
Straightness measurement range	±1.5 mm (0.059 in)
Straightness measurement accuracy[1]	Overall accuracy= Optical reference accuracy + Measurement accuracy
Optical reference accuracy for short range optics[1]	±0.15 M^2 µm where M is the distance the moving optic has traveled in meters; ±0.5 F^2 µin where F is the distance the moving optic has traveled in feet
Optical reference accuracy for long range optics[1]	±0.015 M^2 µm where M is the distance the moving optic has traveled in meters; ±0.05 F^2 µin where F is the distance the moving optic has traveled in feet
Straightness measurement resolution for short range optics	0.01 µm (0.4 µin)
Straightness measurement resolution for long range optics	0.1 µm (4 µin)
Axial separation[2]	0.1 to 3 m (4 to 120 in) with short-range optics, 1 to 30 m (3 to 100 ft) with long-range optics

[1] Straightness measurement accuracy is analogous to the traditional straightedge and indicator method of measuring straightness.

Optical reference accuracy, listed in Table A-7, corresponds to straightedge accuracy. Optical reference accuracy can be eliminated by using straightedge (mirror) reversal techniques

Measurement accuracy corresponds to the indicator accuracy. It depends on the optics being used, and the temperature range. See Table A-8 or A-9.

[2] Axial separation is the distance between the interferometer and the reflector with proper alignment and air temperature between 15 ° and 25 °C (59 ° and 77 °F).

Table A–8. Straightness measurement accuracy for short-range optics

Characteristic	**Specification**
Measurements between 0 and 10 µm (0 to 400 µin)	±3.5 percent of displayed value at 15 to 25 °C (59 to 77 °F)
	±6 percent of displayed value at 0 to 40 °C (32 to 104 °F)
Measurements between 10 and 1,500 µm (400 to 60,000 µin)	±1 percent ±0.25 µm (10 µin) of displayed value at 15 to 25 °C (59 to 77 °F)
	±1 percent ±0.05 µm (20 µin) of displayed value at 0 to 40 °C (32 to 104 °F)

Table A–9. Straightness measurement accuracy for long-range optics

Characteristic	**Specification**
Measurements between 0 and 100 µm (0 to 4000 µin)	±5 percent of displayed value at 15 to 25 °C (59 to 77 °F)
	±7.5 percent of displayed value at 0 to 40 °C (32 to 104 °F)
Measurements between 100 and 1,500 µm (4000 to 60,000 µin)	±2.5 percent ±2.5 µm (100 µin) of displayed value at 15 to 25 °C (59 to 77 °F)
	±2.5 percent ±5 µm (200 µin) of displayed value at 0 to 40 °C (32 to 104 °F)

Note Squareness measurements use the straightness optics. See tables A–7, A–8, and A–9 for straightness specifications.

Table A–10. Squareness measurement specifications

Characteristic	**Specification**
Squareness measurement accuracy for short range optics	$\pm(1.0 + 0.1\,M)$ arcsec $\pm 0.01\,\theta^{1,2}$ for metric measurements; $\pm(1.0 + 0.03\,F)$ arcsecs $\pm 0.01\,\theta^{1,3}$ for English measurements
Squareness measurement accuracy for long range optics	$\pm(1.0 + 0.01\,M)$ arcsec $\pm 0.025\,\theta^{1,2}$ for metric measurements; $\pm(1.0 + 0.003\,F)$ arcsecs $\pm 0.025\,\theta^{1,3}$ for English measurements

[1] Where θ is the calculated out-of-squareness angle in arcseconds.

[2] Where M is the travel distance of the moving optic in meters.

[3] Where F is the travel distance of the moving optic in feet.

Note

Parallelism measurements use the straightness optics. See tables A–7, A–8, and A–9 for straightness specifications.

Table A–11. Parallelism measurement specifications

Characteristic	**Specification**
Parallelism measurement accuracy for short-range optics	$0.06\,M$ arcsec[1] for metric measurements; $F/60$ arcsec [2] for English measurements
Parallelism measurement accuracy for long-range optics	$0.006\,M$ arcsec[1] for metric measurements; $F/600$ arcsec [2] for English measurements

[1] Where M is the travel distance of the moving optic in meters.

[2] Where F is the travel distance of the moving optic in feet.

Note Flatness and way straightness measurements use the angular optics. See Table A–6 for angular specifications.

Table A-12. Flatness and way straightness measurement specifications

Characteristic	Specification
51 mm (2 in) Footspacer (HP 10759A) resolution per step	0.015 µm (0.5 µin)
102 mm (4 in) Footspacer (HP 10759A) resolution per step	0.03 µm (1.0 µin)
152 mm (6 in) Footspacer (HP 10759A) resolution per step	0.045 µm (1.5 µin)
Surface plate reference plane accuracy[1]	The uncertainty of a surface plate flatness measurement is bounded by two parallel planes separated by the values below: 0.03 M^2 where M is the length of the surface diagonal in meters; 0.12 F^2 where F is the length of the surface diagonal in feet.
Lateral offset and flatness range	The combination of lateral offset and maximum flatness deviation must not displace the reflector more than ±1.0 mm from the beam path in any direction.
Maximum accuracy	±0.2 percent of displayed value
Measurement resolution	±0.05 arcsec per meter of distance travelled by the moving optic

[1] These specifications assume the temperature of all optical components is stabilized in the range 15 ° to 25 °C (59 ° to 77 °F), and do not include effects of surface cleanliness.

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